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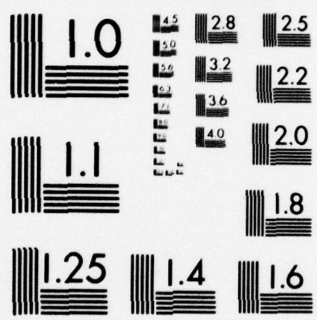

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DREDGED MATERIAL RESEARCH PROGRAM

TECHNICAL REPORT D-78-15

HABITAT DEVELOPMENT FIELD INVESTIGATIONS BOLIVAR PENINSULA, MARSH AND UPLAND HABITAT DEVELOPMENT SITE, GALVESTON BAY, TEXAS

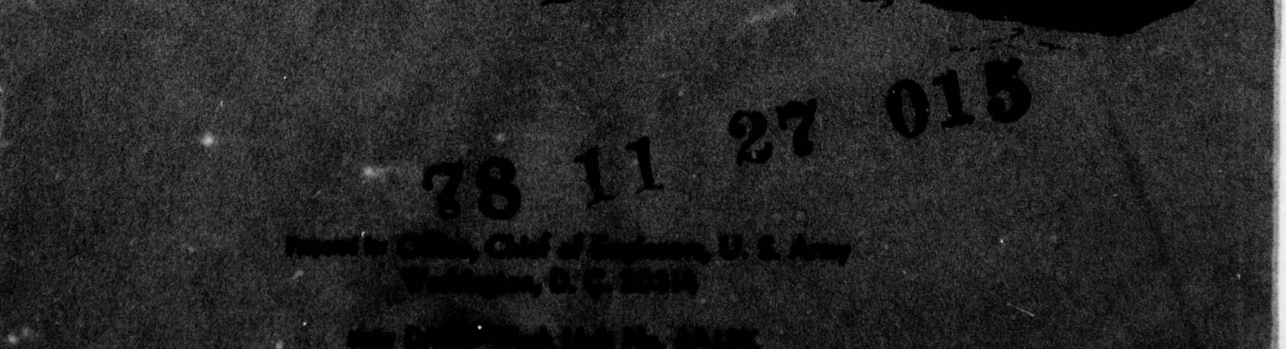
SUMMARY REPORT

by

Hollis H. Allen, Ellis J. Clairain, Jr., Robert J. Diaz
Alfred W. Ford, L. Jean Hunt, B. R. Wells

Environmental Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

August 1978
Final Report



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Under DMRP Work Unit No. [illegible]

HABITAT DEVELOPMENT FIELD INVESTIGATIONS, BOLIVAR PENINSULA
MARSH AND UPLAND HABITAT DEVELOPMENT SITE
GALVESTON BAY, TEXAS

Appendix A: Baseline Inventory of Water Quality, Sediment Quality, and Hydrodynamics

Appendix B: Baseline Inventory of Terrestrial Flora, Fauna, and Sediment Chemistry

Appendix C: Baseline Inventory of Aquatic Biota

Appendix D: Propagation of Vascular Plants and Postpropagation Monitoring of Botanical, Soil, Aquatic Biota, and Wildlife Resources

DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
P. O. BOX 631
VICKSBURG, MISSISSIPPI 39180

IN REPLY REFER TO: WESEV 30 September 1978

SUBJECT: Transmittal of Technical Report D-78-15

TO: All Report Recipients

1. The technical report transmitted herewith represents the results of one of a series of research efforts (work units) undertaken as part of Task 4A (Marsh Development) of the Corps of Engineers' Dredged Material Research Program (DMRP). Task 4A was part of the Habitat Development Project (HDP) and had as its objective the development and testing of the environmental and economic feasibility of using dredged material as a substrate for marsh development.

2. Marsh development using dredged material was investigated by the HDP under both laboratory and field conditions. This report, "Habitat Development Field Investigations, Bolivar Peninsula Marsh and Upland Habitat Development Site, Galveston Bay, Texas; Summary Report" (Work Unit 4A13K), summarizes the activities that occurred during marsh and upland habitat development studies in Galveston County, Texas, between 1975 and 1977. A general discussion of the engineering and biological aspects of the research is presented. The reader is referred to Appendices A through D to this report for a more detailed discussion.

3. A total of nine marsh development sites were selected and designed by the HDP at various locations throughout the United States. Six sites were subsequently constructed. Those, in addition to Bolivar Peninsula, include: Windmill Point on the James River, Virginia (4A11); Buttermilk Sound, Atlantic Intracoastal Waterway, Georgia (4A12); Apalachicola Bay, Apalachicola, Florida (4A19); Pond #3, San Francisco Bay, California (4A18); and Miller Sands, Columbia River, Oregon (4B05). Detailed design for marsh restoration at Dyke Marsh on the Potomac River (4A17) was completed, but project construction was delayed in the coordination process. Marsh development at Branford Harbor, Connecticut (4A10) and Grays Harbor, Washington (4A14) was terminated because of local opposition and engineering infeasibility, respectively. Upland habitat was developed at two sites in addition to Bolivar Peninsula: Miller Sands, Oregon (4B05) and Nott Island, Connecticut River, Connecticut (4B04).

4. Evaluated together, the field site studies plus ancillary field and laboratory evaluations conducted in Task 4A establish and define the range of conditions under which marsh habitat development is feasible.

WESEV 30 September 1978
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Data presented in the research reports prepared under this task will be synthesized in the technical reports entitled "Upland and Wetland Habitat Development with Dredged Material: Ecological Considerations" (2A08), and "Wetland Habitat Development with Dredged Material: Engineering and Plant Propagation" (4A24).

John L. Cannon

JOHN L. CANNON
Colonel, Corps of Engineers
Commander and Director

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19. KEY WORDS (*Continue on reverse side if necessary and identify by block number*)

- Bolivar Peninsula
- Dredged material disposal
- Environmental effects
- Field investigations
- Habitat development
- Habitats
- Marsh development
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- Waste disposal sites

20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

A 2-1/2-year field investigation was conducted at Bolivar Peninsula, Galveston Bay, Texas, to test the feasibility and impact of developing marsh and upland habitats on dredged material. This report summarizes baseline information derived before habitat development operations and results of postdevelopment operations.

Two marsh grass species and nine upland plant species including trees, shrubs, and grasses were planted in test plots on a dredged material site ~~(Continued)~~ CONT'

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20. ABSTRACT (Continued).

lying between the Gulf Intracoastal Waterway and Galveston Bay. Tests were conducted to measure plant survival and performance in response to different fertilizer treatments and planting methods. Plantings of the marsh grasses were made within an intertidal area protected from wave energies by a sandbag dike. Prior to and during plant development, information was collected to document changes in fish and wildlife communities.

Plantings were successful in both and marsh and upland. Marsh grasses surviving and performing well included smooth cordgrass (Spartina alterniflora) and saltmeadow cordgrass (Spartina patens). Upland plants demonstrating good survival and growth were live oak (Quercus virginiana), wax myrtle (Myrica cerifera), winged sumac (Rhus copallina), bitter panicum grass (Panicum amarum), and coastal bermuda grass (Cynodon dactylon var alecia).

Components of the habitat development site, consisting of the planted vegetation and sandbag dike, attracted insects, aquatic organisms, and birds. As the plants developed, the numbers of shore insects, mainly dipterans and beetles, increased greatly in the intertidal study area. Shorebirds associated with marshes moved onto the site and increased in density. The abundance of benthos was 1.5 times greater inside the diked area than outside; within the diked area, the benthos in planted areas was 1.5 times as abundant as the benthos in bare areas.

After less than a year of development, the site provided heterogeneous habitats which tended to support greater use by fish and benthos than is generally associated with sandy shores along Bolivar Peninsula. The field investigation indicated that habitat development is a feasible dredged material disposal alternative.

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PREFACE

This report presents a summary of results of a 2-½-year field investigation (March 1975 to November 1977) of the feasibility and impact of developing marsh and upland habitat on dredged material at a site located at Bolivar Peninsula, Galveston Bay, Texas. The report summarizes baseline information derived before habitat development operations and results of post-development operations. The investigation was conducted as part of the Corps of Engineers' Dredged Material Research Program (DMRP). The DMRP was sponsored by the Office, Chief of Engineers, U. S. Army, and was managed by the Environmental Laboratory (EL), U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi.

The investigation involved two interagency agreements and two contracts. Interagency agreements were made between WES and the U. S. Geological Survey at Austin, Texas and the National Marine Fisheries Service, Gulf Coastal Fisheries Center, Galveston, Texas. Two contracts were made between WES and Texas A&M University and Agricultural Experiment Station, College Station, Texas. Reports resulting from these agreements and contracts appear as the following appendices to this report: Appendix A (Lunz et al. 1978), Appendix B (Dodd et al. 1978), Appendix C (Lyon and Baxter 1978), and Appendix D (Webb et al. 1978).

This investigation could not have been completed without the substantial engineering and construction support provided by the U. S. Army Engineer District, Galveston. The District performed tasks involving site preparation, dike construction and maintenance, fence construction, and logistical support to WES. District Engineers during the period of this investigation were COL Don S. McCoy, CE, and COL Jon C. C. Vanden Bosch, CE.

Preliminary planning of the experimental design and research procedures used in the investigation was accomplished by the staff of the Natural Resources Development Branch (NRDB), Environmental Resources Division of EL. These personnel were Messrs. E. P. Peloquin,

Hollis H. Allen, and John D. Lunz and Drs. J. Scott Boyce and Judith E. Unsicker.

This report was written primarily by the staff of the NRDB. The plants and soils aspects were written by Mr. Hollis H. Allen and Dr. R. B. Wells; the aquatic biology section was written by Dr. Robert J. Diaz and Mr. Ellis J. Clairain, Jr.; and the wildlife section was written by Ms. L. Jean Hunt. Significant contributions were made to the engineering and construction section of the report by Mr. Alfred W. Ford of the Environmental Engineering Division of EL and Mr. Dolan Dunn of the Galveston District who furnished much of the engineering and construction information. Editing was done by Mr. Hollis H. Allen, Ms. Mary K. Vincent, and Dr. Richard A. Cole (Michigan State University and NRDB). Editorial supervision was provided by Ms. Dorothy P. Booth.

The project was under the general supervision of Dr. H. K. Smith, Project Manager, Habitat Development Project of the DMRP; Dr. C. J. Kirby, Chief, Environmental Resources Division; and Dr. John Harrison, Chief, EL.

Commanders and Directors of WES during the period of this study were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

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HABITAT DEVELOPMENT FIELD INVESTIGATIONS
BOLIVAR PENINSULA MARSH AND UPLAND
HABITAT DEVELOPMENT SITE
GALVESTON BAY, TEXAS

SUMMARY REPORT

PART I: INTRODUCTION

1. The U. S. Army Corps of Engineers dredges large volumes of material to develop and maintain the nation's navigable waterways and harbors. This material must be disposed in a cost-effective, environmentally compatible manner. The Corps currently maintains over 30,600 km of waterways and about 1,000 harbors (Boyd et al. 1972). From 1969 to 1972 about 290.5 million cu m were dredged annually, enough to cover 3,108 sq km with 0.91 m of material. Maintenance dredging in the Galveston District alone, containing the research site with which this report is concerned, amounts to nearly 37 million cu m annually, the second largest of all district dredging efforts and 13 percent of all dredging activity.

2. Much of the dredged material in the Galveston District is dumped into the open sea when this is economical and environmentally sound. But because of cost limitations, much material is disposed in shallow water or on land near the dredging project. In many situations it may be possible to use dredged material for various purposes to mitigate undesirable environmental effects. The Dredged Material Research Program was initiated in 1973 at the Waterways Experiment Station with one of its objectives being the development of alternative uses of dredged material. One possible use of dredged material is development of habitat for desirable plants and animals. To investigate this possibility in the research program, several sites were selected at representative dredging projects in the United States. Because of the amount of dredging conducted in the Galveston District and its geographical location, the Bolivar Site was chosen for site representation.

3. The purpose of this report is to summarize and discuss results of studies on the use of dredged material for developing intertidal marsh habitat and upland habitat above high tide on Bolivar Peninsula about 16 km east of Galveston, Texas. Several basic research objectives were defined for study:

a. Document planning, design, construction and subsequent physical changes in the substrate and engineered structures used for habitat development.

b. Develop appropriate planting and cultural practices.

c. Relate the productivity and nutrient content of selected plant species grown on dredged material to the varying chemical and physical properties of the site.

d. Relate animal use to the physical characteristics of the dredged material and vascular plants.

e. Describe the changes, if any, in water quality, sediments, hydrography and aquatic and terrestrial biota following the disposal of dredged material and site development.

f. Document the monetary costs for various aspects of the project such as site development, research and total costs.

g. Document the constraints of social and political institutions in the construction of the habitat development site.

4. The scope of this study included an investigation of conditions at the Bolivar Peninsula site before the commencement of habitat development operations as well as afterwards. Baseline data on water quality, sediments, hydrography, and aquatic and terrestrial biota were taken for two reasons: a) to aid in the planning of habitat development and b) to describe the changes in the above factors following dredged material manipulation and site development. Baseline conditions of the site are reported in Appendices A through C to this report.

5. It should be noted that baseline data were collected from an area 305 m to the west of where habitat development actually occurred. Because of an unanticipated interruption in the Galveston District's dredging schedule, fresh dredged material could not be disposed at

the original site when it was needed. Therefore, the habitat was developed on about two-year-old dredged material to the east of the original site. This move did not constitute a great change in baseline conditions between the two sites since both sites consisted of similar dredged material and had similar physical and biological attributes.

PART II: SITE DESCRIPTION

Geography

6. Several coastal sites in Texas were inspected for potential habitat development during spring 1974. The site at Bolivar Peninsula (Figure 1) was selected in spring 1975 as generally representative of most of the disposal areas along the Texas coast. The site is located within the boundaries of the High Island to Galveston Bay Project, a 64-km portion of the Gulf Intracoastal Waterway. The waterway is maintained by hydraulic pipeline dredging and about 764,000 cu m annually are deposited in disposal areas along the waterway (U. S. Army Corps of Engineers 1974). The disposal area selected for study borders the waterway at km 552. The experimental site consists of 7.3 ha that ranges in elevation between -0.06 and +3.05 m msl (U. S. Army Corps of Engineers 1975).

7. Bolivar Peninsula is an offshore sandbar near the eastern end of a chain of barrier islands extending nearly 960 km along the Mexican and Texas coasts (Lankford and Rehkemper 1969). The peninsula is maintained by littoral transport and occasional transport of coarse sediments by seawater which washes over the barrier into Galveston Bay. Soils on the experimental area are comprised of the Harris, Veston, and Galveston soil series (Godfrey et al. 1973). Saline clays and loams occur in nearby marshes and sands occupy the beaches. Heavy marsh soils generally are overlain by peat (Lay and O'Neil 1942). The principal land uses of the peninsula are ranching and petroleum drilling. Feral goats freely roam in the area.

Meteorology and Hydrology

8. The climate is warm and humid, moderated by the Gulf of Mexico. Average annual precipitation is 106.2 cm and mean temperatures range from a daily low of 4 deg C in winter to a daily high of 34 deg C in summer (Fisher et al. 1972). Rainfall annually exceeds evaporation

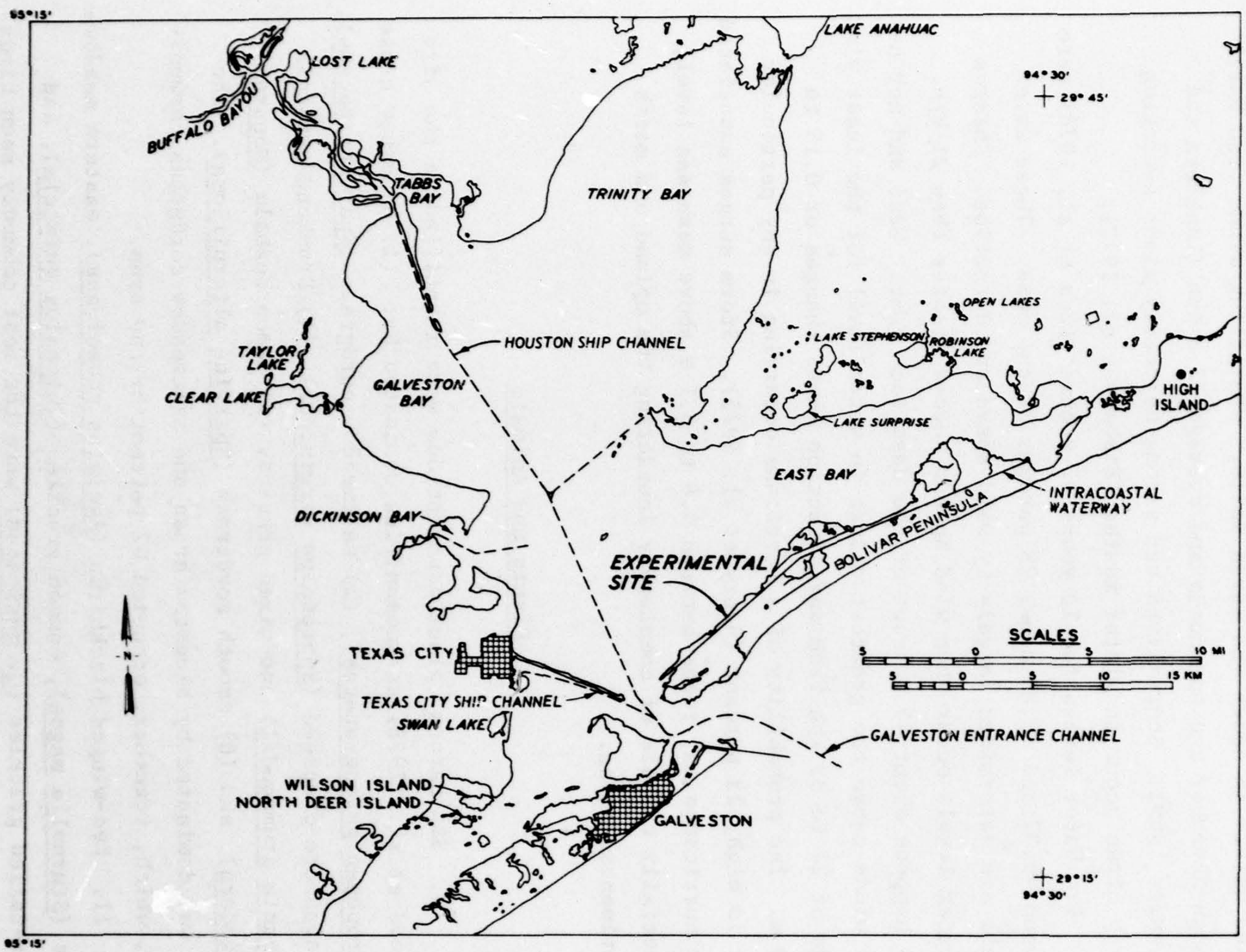


Figure 1. Location of Bolivar Peninsula habitat development site

and plant transpiration by 13 to 20 cm, which is a larger difference than coastal areas farther west. This excess precipitation contributes to groundwater storage and affects the boundary between fresh and saline waters in beach and marsh soils. Prevailing winds from March through November are southerly and average 17.6 kph (Lankford and Rehkemper 1969). Short-lived but strong northerly winds averaging 64 kph often occur in winter months (Fisher et al. 1972).

9. Water levels for 13 years of record (Lunz et al. 1978) were between -0.37 and +0.85 m msl 98 percent of the time. These water levels are determined largely by wind speed and direction. Changes in water levels occur when wind speeds become greater than 21 kph. This happens about 45 percent of the days each year. West and northwest winds cause the greatest change in water level for the least wind. Winds of 21 to 32 kph from any direction cause changes of 0.15 to 0.30 m. The probability of a hurricane occurring in any particular year is high, 23 percent (Henry et al. 1975). Storm surges associated with hurricanes may range between 4.6 to 6.1 m above mean sea level, potentially capable of completely inundating the upland and marsh experimental areas.

Plants and Animals

10. Six natural plant associations were identified on the site by Dodd et al. (1978) as communities dominated by: (1) bluestem grass (*Andropogan perangustatus*), (2) saltmeadow cordgrass (*Spartina patens*), (3) seashore dropseed (*Sporobolus virginicus*), (4) Drummond sesbania (*Sesbania drummondii*) and mixed grasses, (5) lemon beebalm (*Monarda citriodora*), and (6) smooth cordgrass (*Spartina alterniflora*). The area was dominated by bluestem grass and saltmeadow cordgrass communities, which, together, occupied 62 percent of the area.

11. Red-winged blackbirds (*Agelaius phoeniceus*), eastern meadowlarks (*Sturnella magna*), common grackles (*Quiscalus quiscula*), and great-tailed grackles (*Q. mexicanus*) were the most commonly seen birds of the upland. Laughing gulls (*Larus atricilla*) and Caspian terns

(Sterna caspia) frequented the shoreline. The most common mammals were armadillos (Dasypus novemicinctus), raccoons (Procyon lotor), swamp rabbits (Sylvilagus aquaticus), cotton rats (Sigmodon hispidus), and feral goats (Capra hircus). Common land invertebrates were grasshoppers, land snails, fiddler crabs (Uca pugnax), and the tiger beetle (Cicindelidae).

12. There were no submerged aquatic plant communities at the site (Lyon and Baxter 1978). Associated zooplankton were mostly barnacle larvae and copepods. Among the abundant larger invertebrates were white shrimp (Penaeus setiferus) and several species of marine worms (Polychaeta). Extensive oyster beds occur in Galveston Bay but the nearest was 5.9 km from the site (Lyon and Baxter 1978).

PART III: ENGINEERING AND CONSTRUCTION

Methods and Materials

Site preparation

13. The plans for habitat development as mentioned in the introduction, originally specified that substrate be composed of freshly deposited dredged material, but instead, because of an interruption in the dredging schedule, habitat was developed on a two-year old disposal area 305 m east of the original site. The substrate had been hydraulically deposited over older deposits of dredged material. Because the material had been routinely deposited without care for elevational uniformity, it required landscaping to meet experimental specifications. All existing vegetation was cleared from the site before experimentation. A dike of sandbags was constructed to dissipate wave energies within the intertidal zone at the experimental site and a fence was built to exclude goats, rabbits, and other potentially destructive animals.

14. The site design, size, and construction specifications are illustrated in Figure 2. The site was surveyed and graded to provide space for two main experimental plantings, an intertidal area for marsh plants, and an area above tide for upland plants. Based on estimated tolerances of the experimental plants to inundation, the intertidal area was graded to a prespecified slope of 0.67 percent ranging between -0.15 to +0.64 m msl. All of the area inside the fence was graded including the area outside the dike of sandbags. The upland area was not precisely graded but was back-dragged to level mounds and depressions. This was done above +0.64 m msl, considered to be the upper level of the intertidal experimental area. A contract was awarded for the land preparation on 29 January 1976, and the job was completed on 5 March 1976.

Dike design and construction

15. Based on hydrodynamic data developed by the U. S. Geological Survey, marsh development was not expected to succeed without

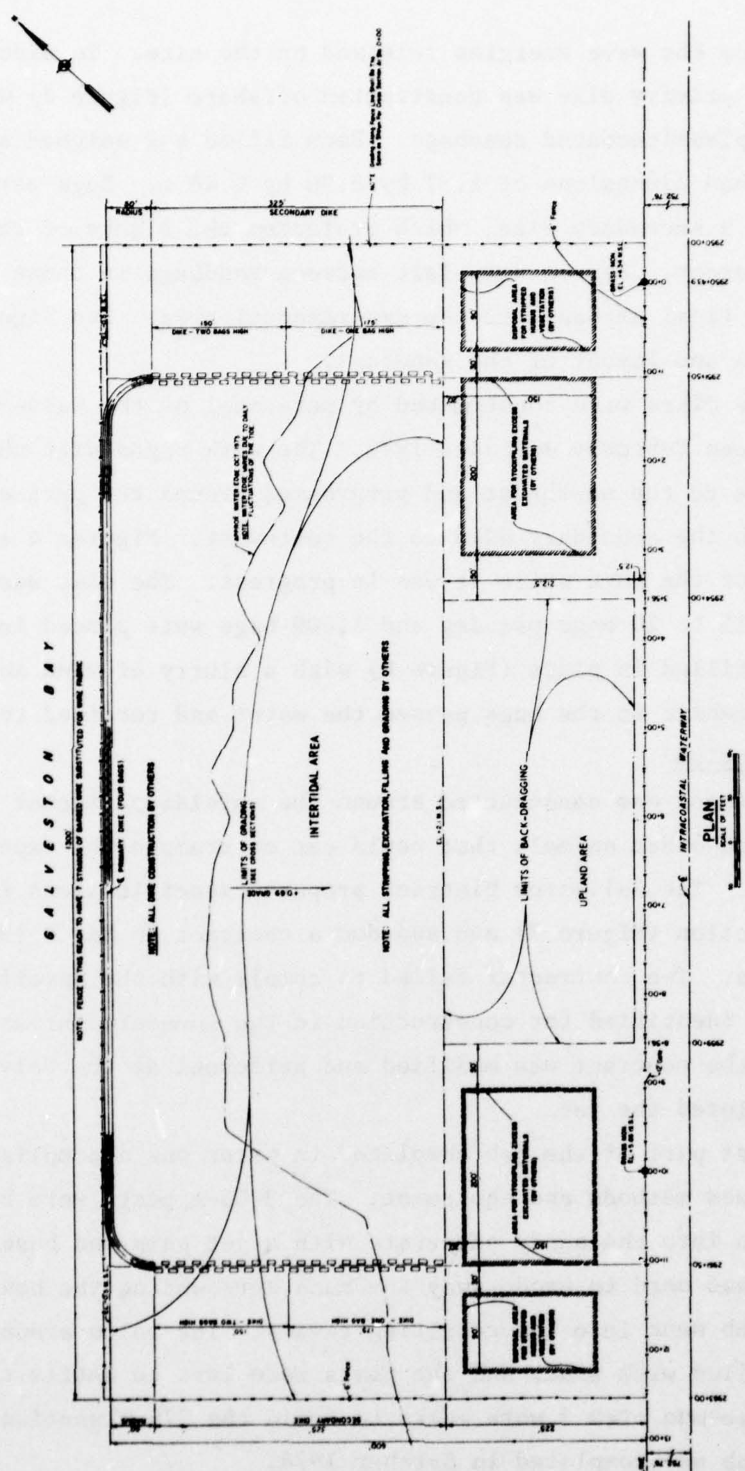


Figure 2. Site design, size, and construction specifications

protection from the wave energies released on the site. To dissipate the energy, a primary dike was constructed offshore (Figure 2) with woven-nylon, plastic-coated sandbags. Each filled bag weighed about 3,175 kg and had dimensions of 1.37 by 2.90 by 0.46 m. Bags were also used to build a secondary dike, which protected the flanks of the experimental areas. Spaces were left between sandbags in these dikes to allow free tidal exchange in the experimental area. See Figure 3 for dimensions and layout of the sandbags.

16. The dikes were constructed by personnel of the Galveston District between February and June 1976. The work began with the secondary dike to the northeast and progressed around the perimeter, finishing with the secondary dike to the southwest. Figures 4 and 5 show aspects of the work while it was in progress. The dike was built at a rate of 15 to 20 bags per day and 1,000 bags were placed in total. Each bag was filled in place (Figure 6) with a slurry of sand and water. The pervious fabric in the bags passed the water and retained the sand.

<u>Fence construction</u>

17. A fence was constructed around the outside perimeter to exclude goats and other animals that could eat or trample the experimental plantings. The Galveston District prepared specifications for fence construction (Figure 7) and awarded a contract in March 1976 for its completion. The contractor failed to comply with the specifications clearly identified for construction in the inundated areas of the site, so the contract was modified and personnel at the Galveston District completed the job.

18. That part of the job completed in water was accomplished with specialized methods and equipment. The 3.05-m posts were hydraulically driven into the sandy substrate with a jet pump and hose. A jet of water was used to erode away the sand surrounding the base of the post, which sank into the resulting cavity. The holes around the posts were filled with sand, and the posts were left to settle tightly. It took a three-man crew 5 work weeks to build the 579-m section in water. The job was completed in October 1976.

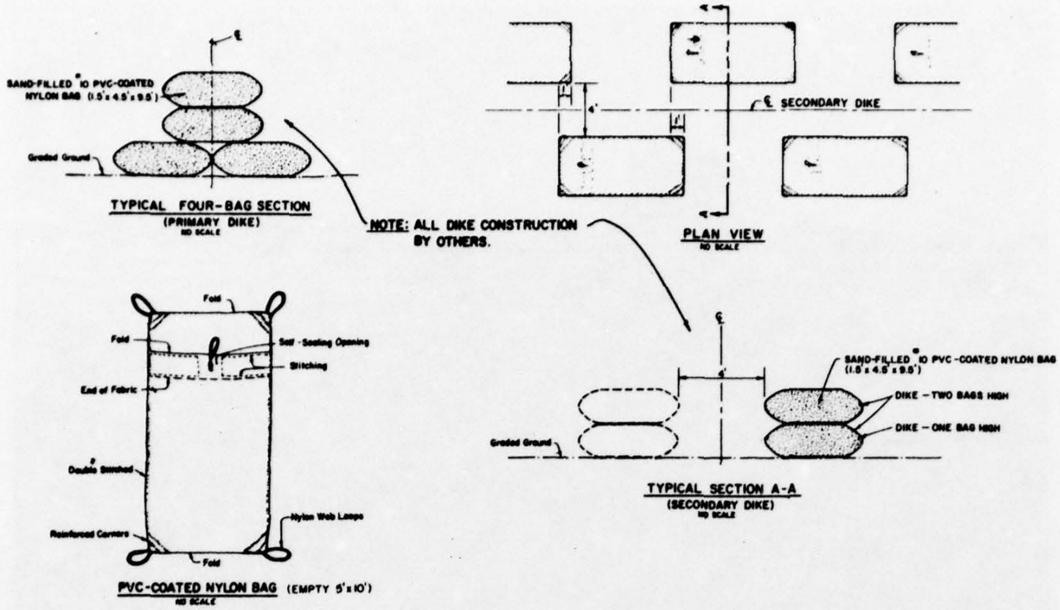


Figure 3. Dimensions and layout of sandbags

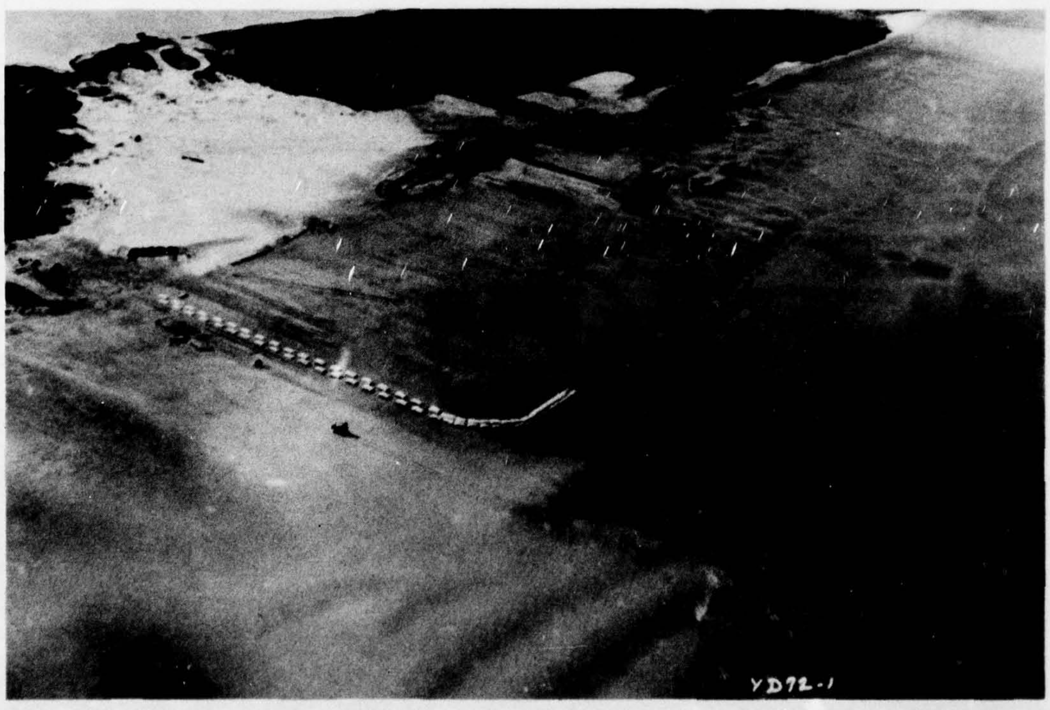


Figure 4. Site development activities showing grading and primary and secondary dike construction

Figure 5. Dike construction showing equipment in operation

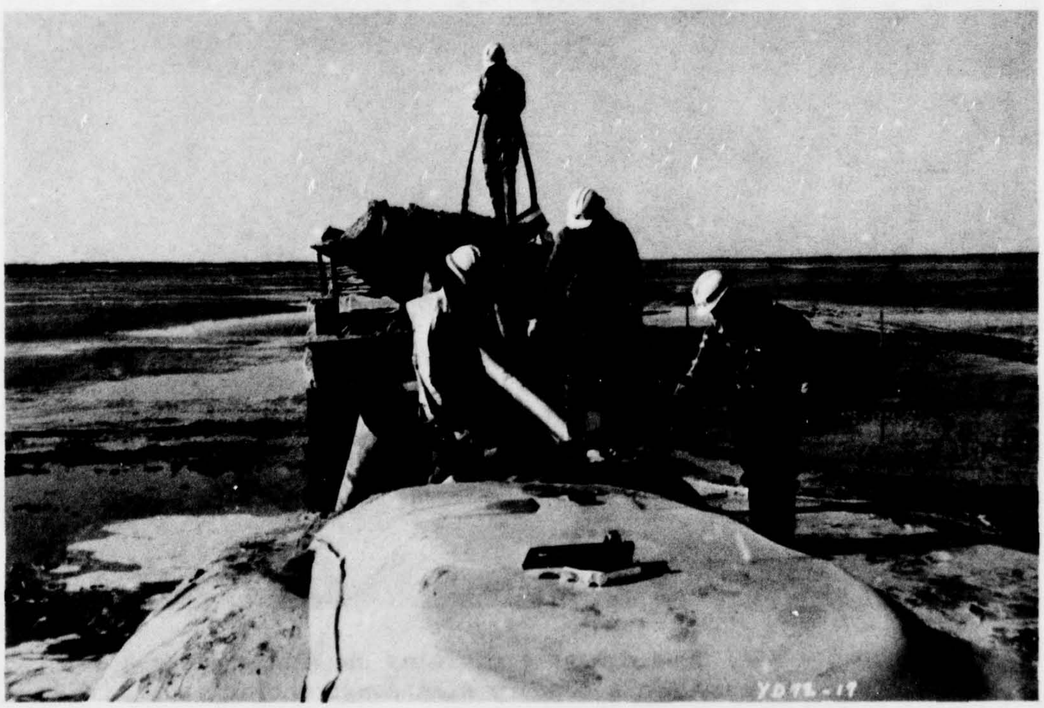
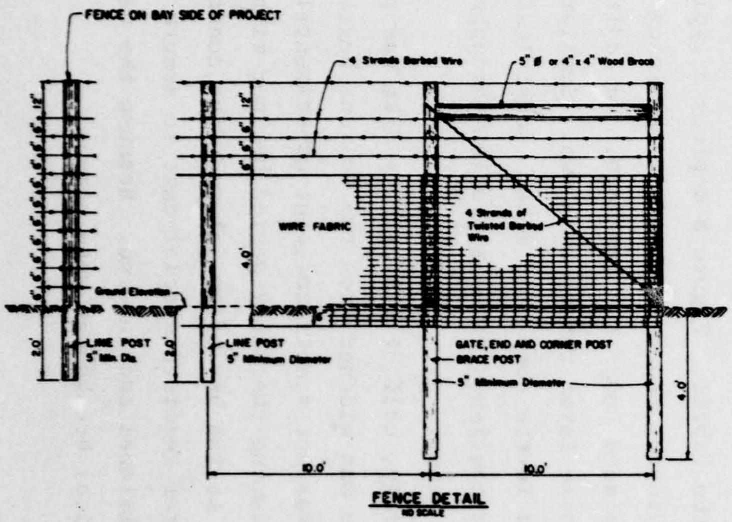


Figure 6. Sandbags being filled in place with slurry of sand and water



FENCE NOTES:

1. MAXIMUM LENGTH OF UNBRACED FENCE SHALL NOT EXCEED 500 FEET. BRACING POST SHALL BE EQUIVALENT TO CORNER POST AND SHALL BE BRACED EACH SIDE WITH DIAGONAL BRACES SIMILAR TO CORNER BRACING.
2. ALL METAL SHALL BE HOT-DIP GALVANIZED.
3. WIRE SHALL BE FASTENED TO WOOD POST WITH GALVANIZED STAPLES MADE OF NO. 9 WIRE.
4. FENCE AND GATES SHALL BE FURNISHED COMPLETE WITH ALL NECESSARY FITTINGS.
5. WIRE FABRIC TO BE NO. 12.5 GAGE WIRE, WELDED IN 2 VERTICAL-4 HORIZONTAL INCH MESH, FOUR FEET IN HEIGHT.
6. BARBED WIRE SHALL BE NO. 12.5 GAGE, TWO POINT, MEETING FEDERAL SPEC RR-F-221 FOR ZINC COATING, SPACED AS SHOWN ON FENCE DETAIL.
7. CORNER POST SHALL BE INSTALLED AT ALL CORNERS.
8. CORNER AND BRACE POSTS SHALL BE NOTCHED AND NAILED WHERE WOODEN BRACE BUTTS POST.
9. LINE POSTS SHALL BE 8 FEET LONG, 5 INCH DIAMETER, CORNER AND BRACE POSTS SHALL BE 10 FEET LONG, 5 INCH DIAMETER, PEELED, PENTA TREATED, EXCEPT AS OTHERWISE NOTED.
10. GATE SHALL BE 12 FEET WIDE 6 FEET HIGH WITH NO. 12.5 GAGE WIRE, 2 VERT - 4 HORIZ INCH MESH, 6 FEET IN HEIGHT. GATE SHALL BE FRAMED WITH 1 7/8 INCH O.D. GALVANIZED PIPE.

Figure 7. Fence design and specifications

Results and Discussion

Grading and clearing

19. Grading and clearing produced a satisfactory environment for experimentation. Erosion rates were not uniform on the site following grading so elevations tended to vary more with time. All machinery used for grading proved effective but a light bulldozer proved advantageous in the intertidal areas while a heavier bulldozer was more suitable for upland conditions. A rubber-tired, front-end loader performed well moving material over the site.

Dike construction

20. The dikes afforded the protection needed at the site but severe maintenance problems arose before the dike was completed. At some places along the primary dike, filled sandbags began to sink rapidly and, in some cases, lose sand. Two modes of dike failure occurred: channel development beneath the point of two adjoining bags and substrate scouring along the face of the dike. It was soon realized that the bags would require periodic refilling to make up for leaching through the fabric. Figure 8 depicts a typical dike failure. In an attempt to prevent scour in the dike remaining to be built, filter cloth was placed under the sandbags. In addition, four sandbags were used in the base layer rather than two. Smaller sandbags were used to repair breaches in the completed dike. Regardless of these efforts, dike deterioration continued to be a problem throughout the study period because of scour.

21. Ultimately, half of the primary dike was placed on filter cloth and the base was widened from two to four bags. Even though half of the dike was not stabilized, the experimental area was protected from wave action during the study period but not without costly effort. High water levels in the bay often delayed dike construction. Placing sandbags under water required special care to assure that the bags were properly positioned and secured. Because the salt water was corrosive, mechanical breakdowns were common.

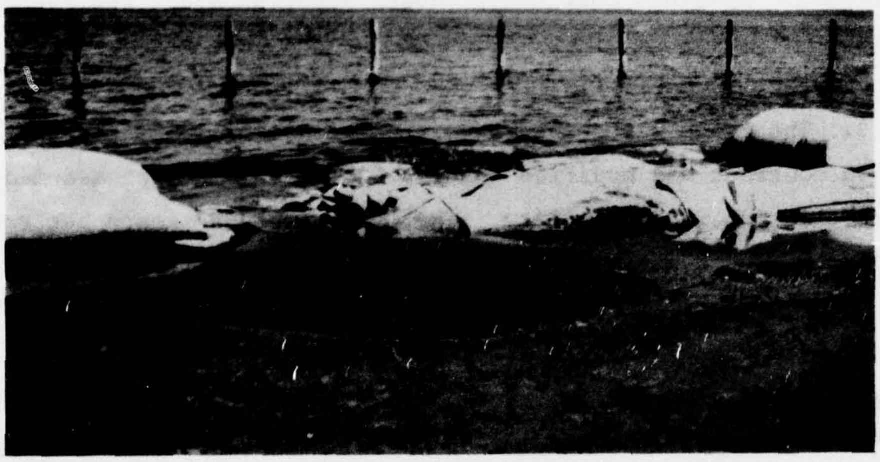


Figure 8. Typical failure of primary dike

Recommendations for dike protection

22. It is recommended that in future construction of protective dikes, a representative section of test dike be built before the main job is initiated. A small test section was constructed at the Bolivar site, but it was too small to identify the erosion problems that were encountered later. Future dikes of this type in this area should be built on filter cloth to reduce the effects of erosion. It is noteworthy that where filter cloth was placed under the base layer of sandbags no maintenance was required. An alternative design, which might reduce erosion effects even further, would be the construction of two parallel lengths of alternating 15-m lengths of dike separated by 9 to 12 m. This design would protect the site and also allow numerous water exchange openings that would reduce scouring along the faces of the dike.

Fence construction

23. The fence was completed without complication after the construction contract was modified and the Galveston District assumed full construction responsibility. The fence excluded goats but rabbits were able to pass through the 6 x 13 strands per m wire mesh. To exclude rabbits, chicken wire was placed at the base of the fence by personnel from Texas A&M University.

Costs of site development

24. Costs are itemized in Table 1. These costs are generally inflated because of the research specifications required. More was spent on planning, design, and construction than would have resulted without the research goals in mind. The dike cost more than anticipated because of maintenance requirements. The use of filter cloth should significantly reduce maintenance costs. Costs of plant procurement and planting were not documented at the Bolivar site but they would be higher than for routine habitat development because of the complex experimental design used. Zarudsky (1975) reports that planting smooth cordgrass on dredged material in Long Island cost $5,565/ha for plant procurement, planting labor, fertilizer and plant shipment. Woodhouse et al. (1972) found that procurement and hand transplanting

of smooth cordgrass required 134 man-hours/ha in North Carolina.

Summary and Conclusions

25. Dike construction and other site development operations probably were necessary at Bolivar to establish the marsh habitat. However, less expensive techniques for barrier construction should be considered for future projects. Where reasonable, the use of dredged material to build a barrier should be considered for areas with intense wave energies. Fence construction also seemed to be absolutely necessary and may be required in any area where large grazing animals are common.

PART IV: PLANTS AND SOILS

Methods and Materials

Intertidal zone

26. Experimental design. The 7.3-ha site was divided into intertidal and upland zones (Figure 9). Each zone had its own experimental design (Figure 10). The intertidal zone was divided equally into three elevational tiers, tiers 1, 2, and 3 (Figure 10). The percentages of time that these tiers were inundated by tidal water from 1 February to 31 August 1977, the majority of the growing season, was 80 to 93 percent for the lowest tier (tier 1), 9 to 80 percent for the intermediate tier (tier 2), and 1 to 9 percent for the upper tier (tier 3). Each elevational tier was divided into three blocks of 30 plots each. The 6 by 10-m plots were randomized for experimental treatment according to the schedule provided in Table 2. Within each block, 10 plots each were planted with smooth cordgrass, saltmeadow cordgrass, or left unplanted. For each 10 plots, five were sprigged and five were seeded. Each of these five plots was fertilized in a different manner, including no fertilization at all. The 10 unplanted plots were also split into two sets of five fertilization treatments. In total, three plots in each elevational tier were treated identically for each of the 30 different treatment combinations. This design was later modified by dividing some plots in half in order to refine the analysis of elevational effects on plant performance and to analyze the effect of different planting times on sprig growth of smooth cordgrass. Details of this modification can be found in Webb et al. (1978).

27. In the intertidal zone, two pairs of long, planted and unplanted plots were established outside the dike and two pairs were established inside the dike but outside of the monotypic marsh plots (Figure 9). These plots were sprigged with alternating rows of smooth cordgrass and saltmeadow cordgrass but were not fertilized. They provided a qualitative evaluation of dike effects on plant survival and growth.

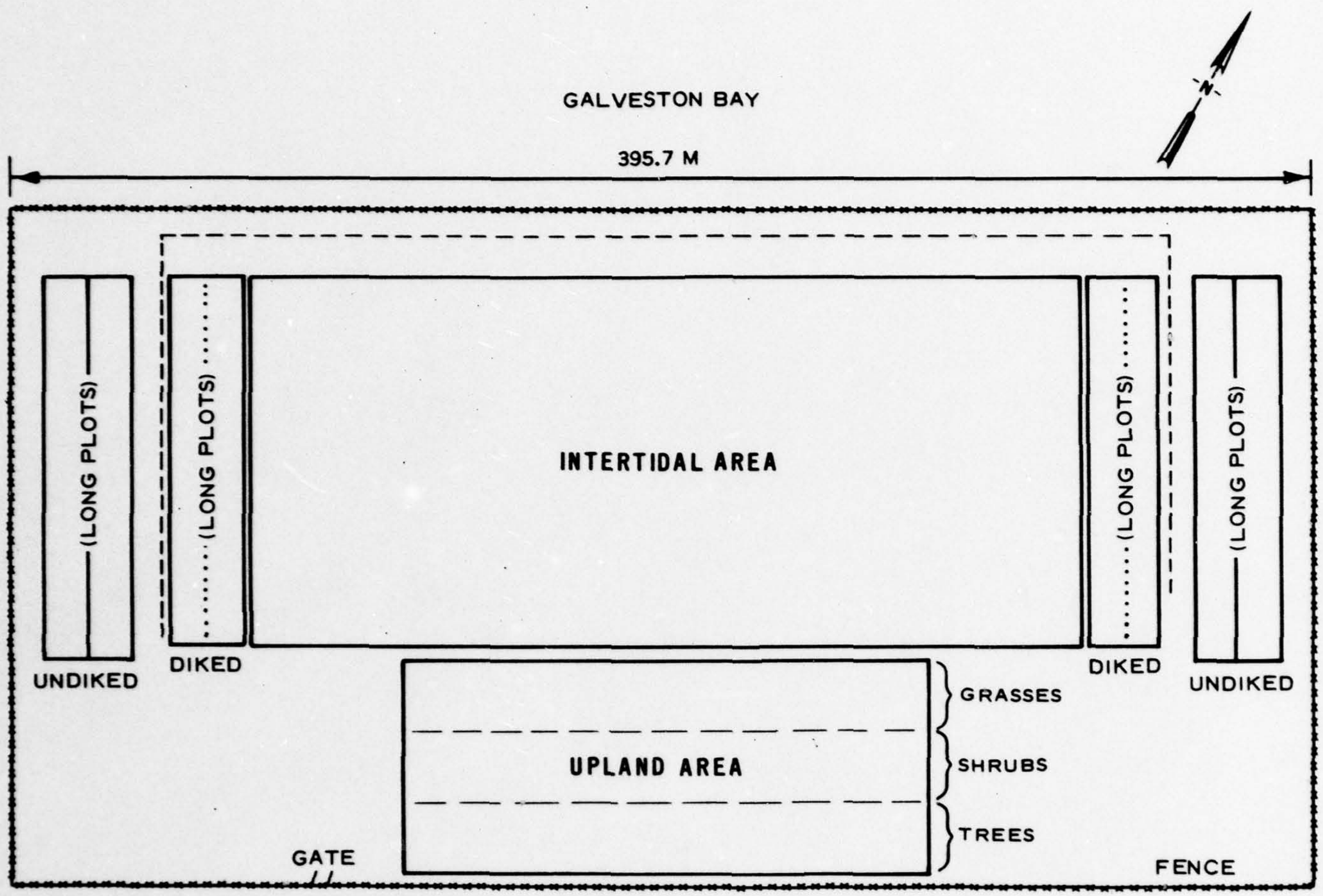


Figure 9. Field layout of the site

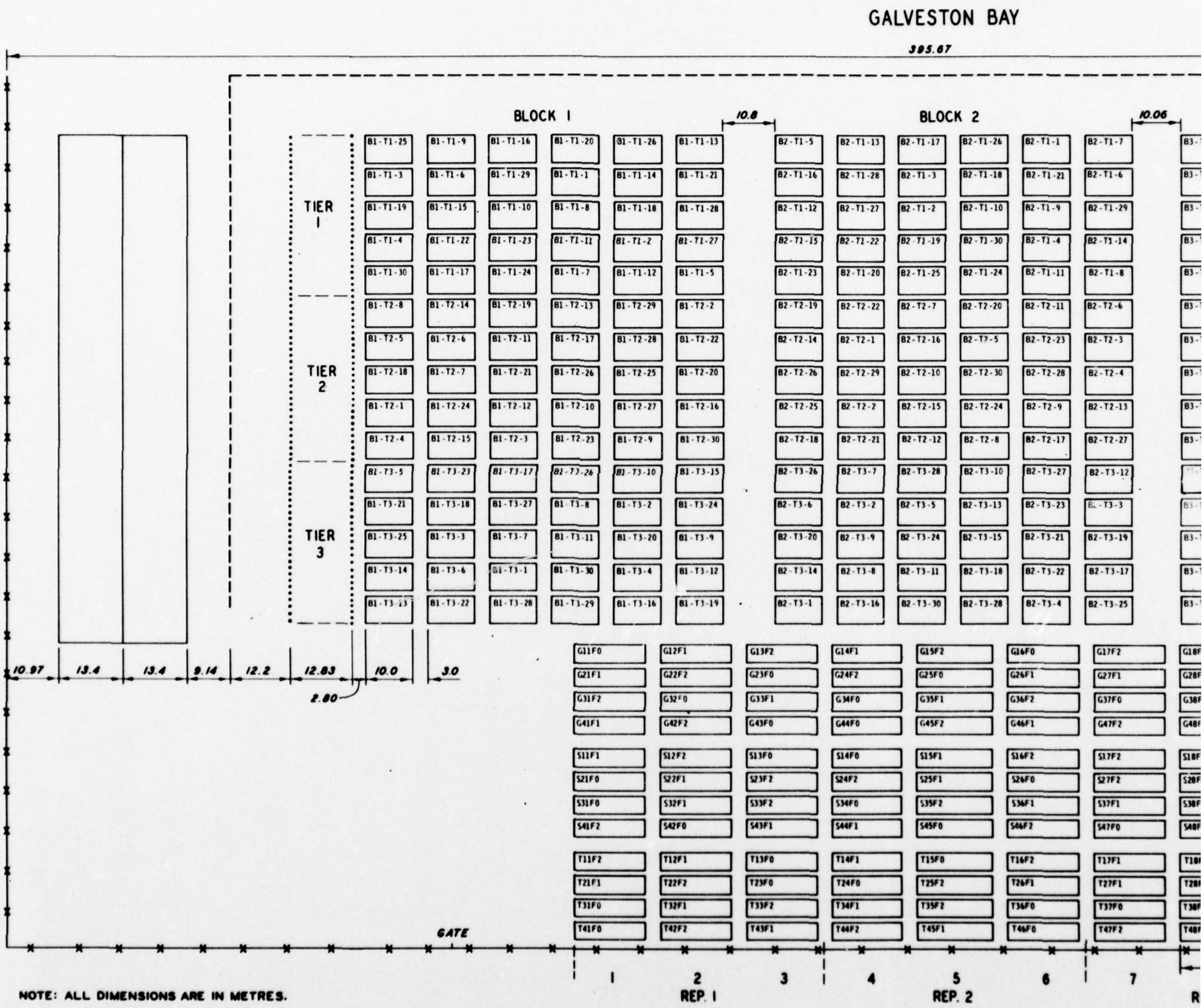
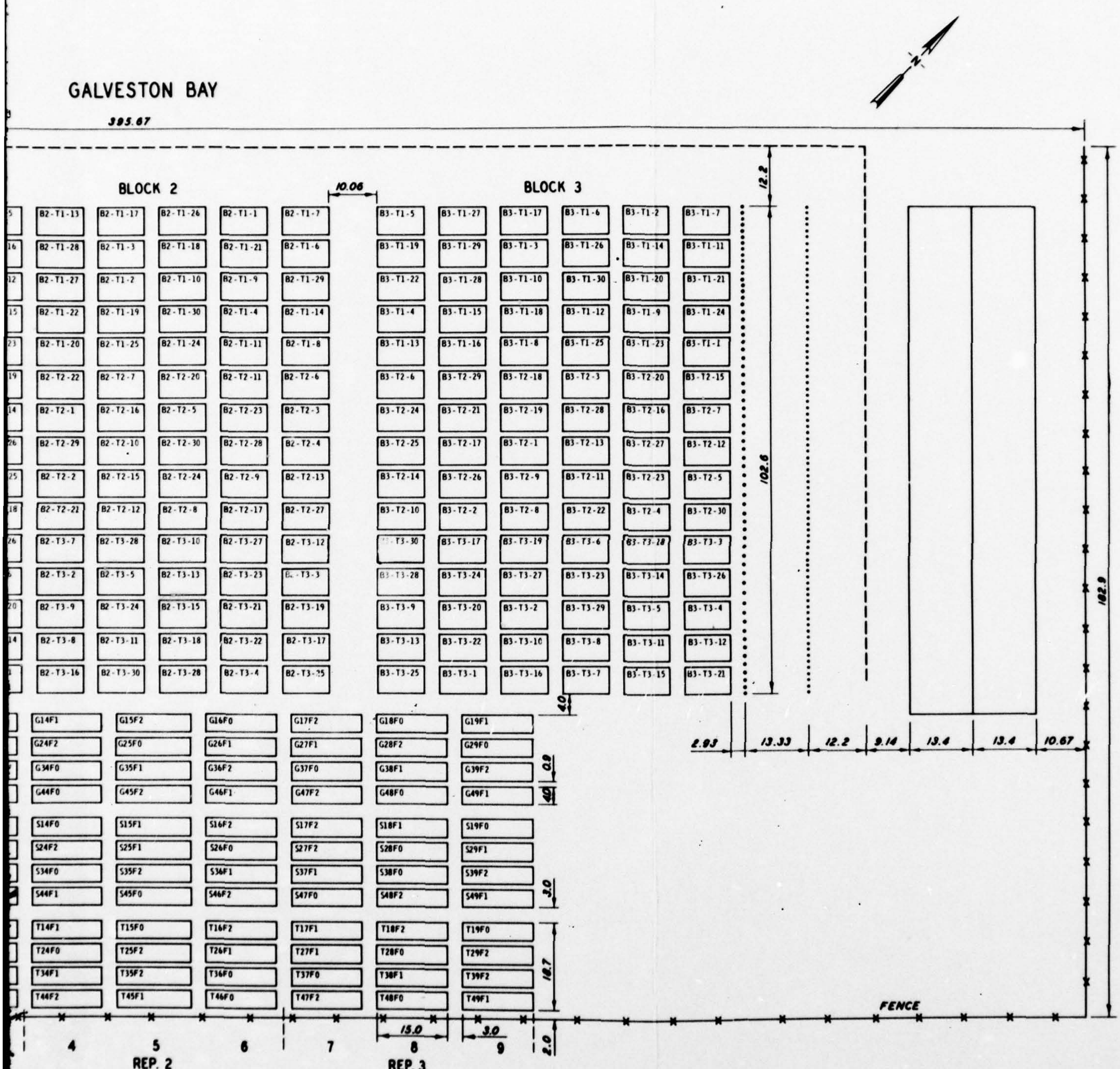


Figure 10. Experimental plot layout

[redacted]



re 10. Experimental plot layout

28. Experimental procedure. The sprigged plots of smooth cordgrass and saltmeadow cordgrass were fertilized and planted 22 July through 4 August 1976 for a summer planting, 1-4 February 1977 for a winter planting, and 11-12 and 30-31 May 1977 for a spring planting. The two species were seeded and fertilized 21-23 March 1977. Germination was tested prior to seeding to determine the appropriate storage conditions and seeding rates. Details of seed germination tests, plant procurement, plant handling and planting techniques can be found in Webb et al. (1978). Following planting, the plots were monitored for plant survival, performance, and production from 22 August 1976 to 15 November 1977. Evaluations were made at least once a month except for January, March, and August 1977.

29. The following characteristics were measured by non-destructive sampling: plant height, plant density, number of stems per plant, number of stressed or stable plants, vegetative reproduction, percent foliar cover, and the number of plants with flowers, seed heads, and new growth. Biomass of roots and shoots was destructively sampled during November of each year using a circular core, 25 cm deep and covering a 0.1-m^2 area. Three 1 by 3-m quadrats per plot were used for permanent, non-destructive sampling while destructive plant samples were selected at random from the remainder of the plot. Other details of the methodology can be obtained from Webb et al. (1978).

Soils in the intertidal zone

30. Prior to planting and fertilization in July 1976, the intertidal substrate was sampled to characterize baseline conditions from which to make comparisons after planting and fertilization. Six 30-cm-long cores were taken on 29 June 1976 from the intertidal sites using a 7.6-cm diameter polyvinylchloride (PVC) pipe. Three cores were from areas commonly submerged and three were from portions of the site subjected to intermittent flooding. The cores were sectioned into 0-15 and 16-30-cm segments and analyzed. Shortly after planting on 18 August 1976, nine 105-cm cores were taken from the high fertilizer level, smooth cordgrass plots and handled as described above.

31. In subsequent analyses for site monitoring, a composite sample of ten cores was taken from each of the 270 marsh plots and the 35 intertidal reference plots on 11 November 1976, 27 June 1977, and 14 October 1977. Cores were taken to a depth of 30 cm with a 2.5-cm diameter soil tube. The samples were frozen in dry ice and transported to the laboratory where the entire 30 cm of the ten cores were blended and subjected to chemical analyses. Deep 105-cm cores were taken on 11 November 1976, 27 June 1977, and 14 October 1977, and analyzed by 15-cm segments.

32. All soil samples were analyzed for percent soil moisture, soil pH, total Kjeldahl nitrogen, ammonium nitrogen, nitrite and nitrate nitrogen, and oxalate extractable phosphorus. For all samples other than those taken on 11 November 1976 and 27 June 1977, analyses also included organic matter, particle size, cation exchange capacity, exchangeable bases, salinity, total phosphorus, total sulfide, and lime requirement. Other measurements included precipitation, soil temperature, elevation, and the potential for chemical reduction and oxidation (redox potential). Precipitation was collected and analyzed for concentrations of nitrogen, phosphorus, calcium, potassium, and sodium. Details of methodology may be found in Webb et al. (1978).

Upland Zone

33. Experimental design. The experiment in the upland area was designed to study survival and growth of three vegetational forms: trees, shrubs, and grasses. The trees included sand pine (*Pinus clausa*), live oak (*Quercus virginiana*), and salt cedar (*Tamarix gallica*). Included among shrubs were wax myrtle (*Myrica cerifera*), gulf croton (*Croton punctatus*), and winged sumac (*Rhus copallina*). The grasses were coastal bermuda grass (*Cynodon dactylon* var *alecia*), bitter panic (*Panicum amarum*), and bluestem (*Andropogan perangustatus*). Grasses were planted in rows along the lowest elevations in the upland area, then shrubs at the intermediate elevations, and trees at the highest elevations (Figure 9). Each of the three elevational zones was divided into four rows of plots; each plot was 4 by 15 m on a side, and three rows were planted with the three species of each vegetational form

(Figure 10). The fourth row in each zone was left unplanted. The plots in each row were divided into three sets or replicates of three plots each and each set in the three plots was fertilized differently, including one plot that was not fertilized. See Table 3 for a schedule of the treatments. This design later was modified to test the effects of additional fertilization during the second growing season on half plots of coastal bermuda and bitter panic grasses. Specific details of the experimental design and analysis can be obtained from Webb et al. (1978).

34. Experimental procedure. All upland transplants were collected from local sources with the exception of sand pine and live oak, which were purchased from nurseries in Georgia and Louisiana, respectively. The upland was planted from 29 June to 8 July 1976 and from 19 January to 9 February 1977. The grasses were sampled from three, 1 by 3-m quadrats located in each third of each plot. Because only 16 trees and shrubs were planted per plot, all of them were measured for all characteristics except for destructive estimates of biomass. The non-destructive measurements for grasses included percent survival, plant height, miscellaneous environmental effects, vegetative reproduction, times and amounts of fruiting and seeding, animal damage, percentage of foliar cover, and number of invading species and plants per quadrat. Non-destructive measurements for the trees and shrubs consisted of percent survival, plant height, and number of invading species and plants. Non-destructive measurements were made on 2 September 1976, 9 November 1976, 21-22 June 1977, and 22 September to 5 October 1977. The biomass of plant roots and shoots was sampled destructively by taking three plants from each quadrat at the end of the growing season. Grasses were destructively sampled from 9-19 November 1976, and 22 September to 6 October 1977. Shrubs and trees were sampled for biomass only at the end of the 1977 growing season from 22 September to 6 October. Refer to Webb et al. (1978) for details about plant procurement, handling, fertilization, and measures of plant performance.

Soils in the Upland Zone

35. Three 30-cm cores were taken on 29 June 1976 from the upland site. Sampling techniques, handling, and analyses were the same as those described for the initial sampling of the intertidal zone. No further substrate sampling was conducted in the upland.

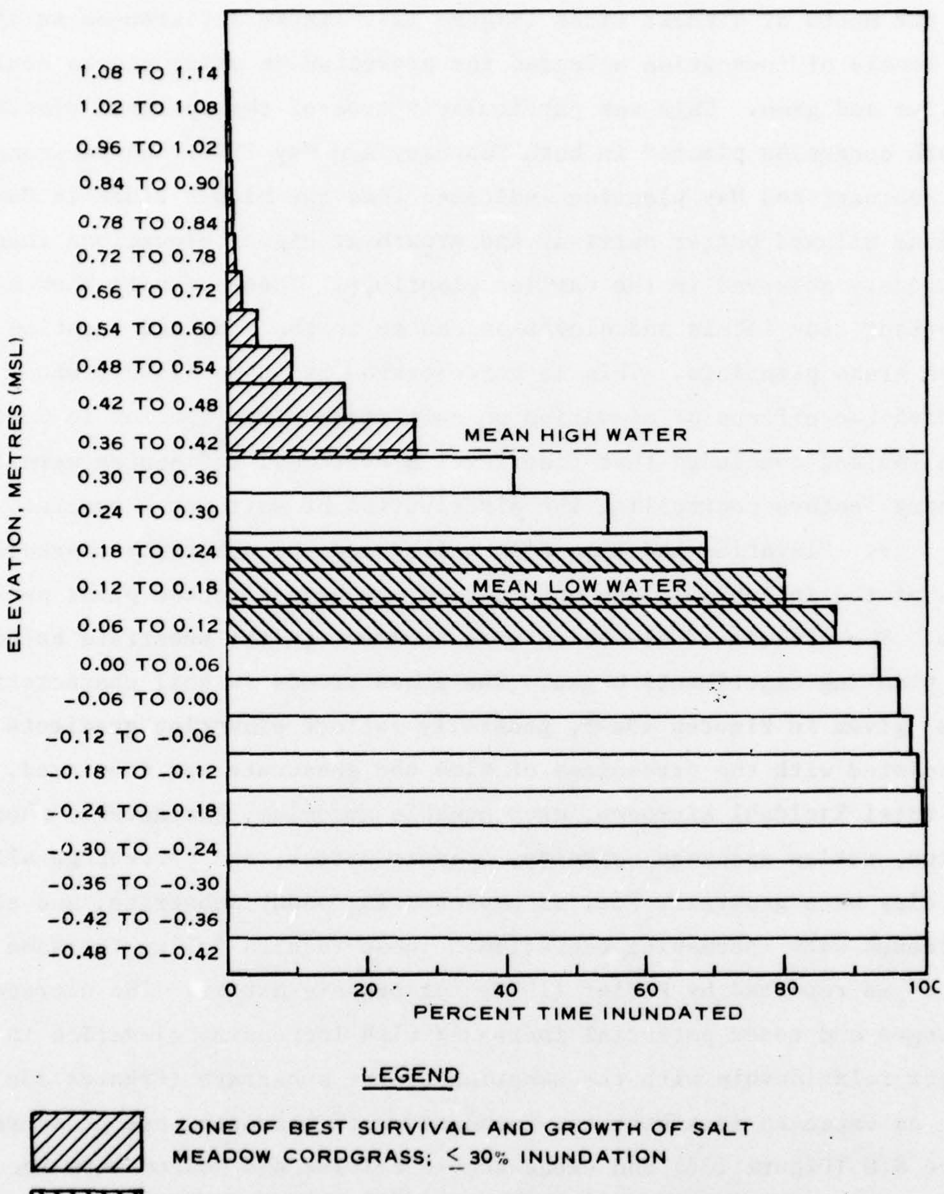
Results and Discussion

Intertidal Zone

36. Elevation. Elevation determined the percentage of time that the plants were inundated and was a key factor determining planting success, subsequent plant performance, and the distribution of soil characteristics. Tide levels were strongly influenced by wind direction and velocity and were highly variable (for example, tides covered an elevation near mean high tide half of the time for a 34-day period in spring 1977). This introduces a confounding variable into the interpretation of the elevational and seasonal factors influencing plant success. However, observations at this site confirm observations at other habitat development sites regarding the relative elevations at which smooth cordgrass and saltmeadow cordgrass survive and grow (Kruczynski et al. 1978, Cole 1978). That is, smooth cordgrass grew most successfully in the lower tidal range whereas saltmeadow cordgrass was most successful in the upper third of the tidal range.

37. Smooth cordgrass survived and grew best at lower elevations, 0.06 to 0.21 m above mean sea level, where tidal inundation occurred 69 to 87 percent of the time from 1 February to 31 August 1977 (Figure 11). However, sprigs of this species were partially successful at all elevations of the intertidal area, except at approximate mean high water which will be discussed below. Saltmeadow cordgrass performed best in the upper intertidal zone at an elevation above 0.37 m msl. Few plants of this species survived where the substrate was inundated more than 25 to 30 percent of the time (Figure 11).

38. Tidal ranges were variable from one season to another because of the controlling influences of winds. During the period of

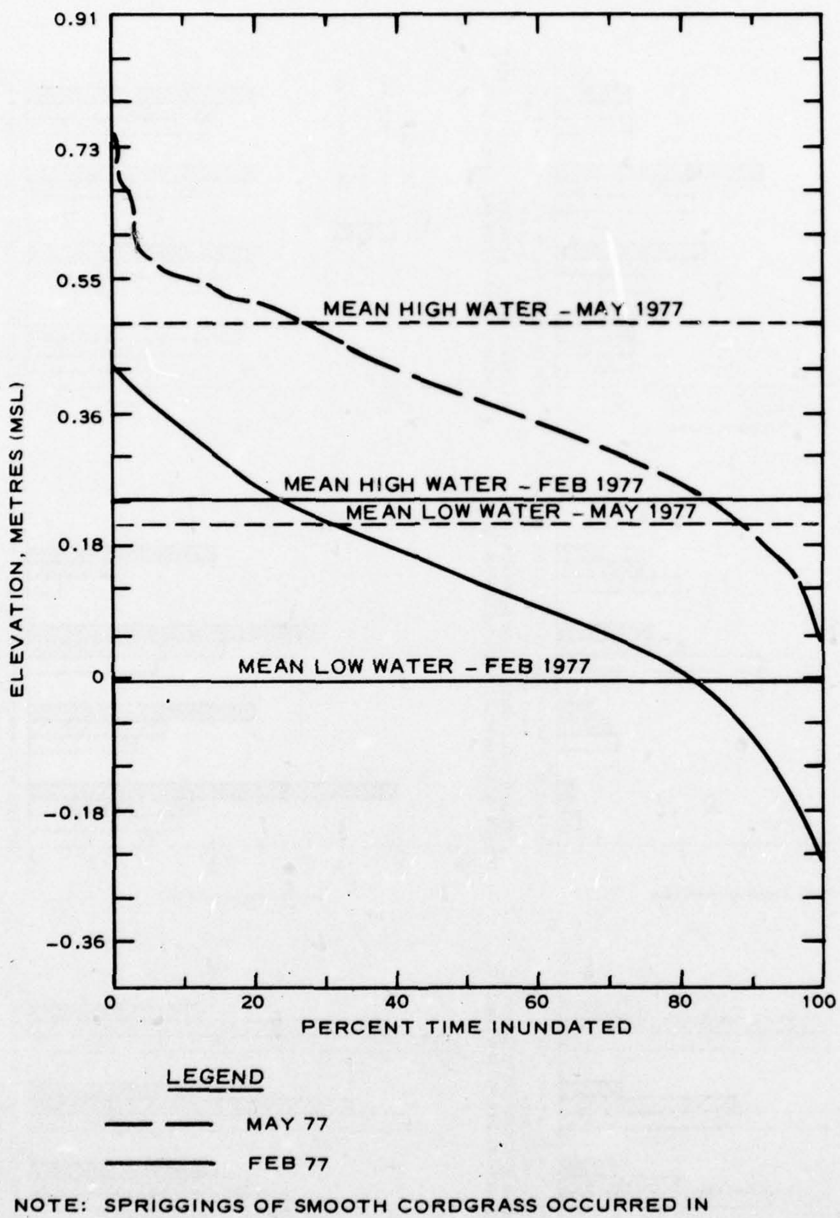


NOTE: TIDE DATA ARE FROM 1 FEBRUARY TO 31 AUGUST 1977, A PERIOD COVERING THE MAJORITY OF THE GROWING SEASON.

Figure 11. Elevational zones of best survival and growth of saltmeadow and smooth cordgrass with percent inundation

tidal monitoring, February was the month of lowest tides whereas May was the month of highest tides (Figure 12). These differences in tides and levels of inundation affected the elevation at which plants could survive and grow. This was particularly true of the sprigged plants of smooth cordgrass planted in both February and May 1977. Comparisons of the February and May planting indicated that the higher tides in May to June allowed better survival and growth at higher elevations than previously observed in the earlier plantings. These results show how important tide levels and elevation can be to the time and location of marsh grass plantings. This is corroborated by Adams (1963), who studied the effects of elevation on salt marsh plant species in North Carolina and concluded that tide level elevational influences were the primary factors controlling the distribution of salt marsh species.

39. Elevation and time also influenced the substrate characteristics of the intertidal zone and in turn may have affected plant performance. The effects of elevation were apparent in the substrate before the planting experiments began. The gross trends in soil characteristics, given in Figures 13a-f, generally reflect elevation gradients associated with the percentage of time the substrate was inundated. The total Kjeldahl nitrogen, exchangeable ammonium, extractable phosphorus, cation exchange capacity, organic matter, and percentage silt and clay were generally low, as expected for sandy substrate, and all decreased with increasing elevation. These results follow the same trends as reported by Fedler (1977) for organic matter. The nitrate nitrogen and redox potential increased with increasing elevation in direct relationship with the aeration of the substrate (Figures 13c and e). As expected in substrates inundated with seawater, the pH averaged above 8.0 (Figure 13f) and exchangeable calcium and sodium were the most concentrated exchangeable bases. After planting and fertilization, the same elevational trends remained but concentrations of organic matter, nitrogen and phosphorus generally increased over time. The presence or absence of plants appeared to have no appreciable effect on the levels of total Kjeldahl nitrogen or extractable phosphorus in the substrate as can be seen in Figures 14a and b.



NOTE: SPRIGGINGS OF SMOOTH CORDGRASS OCCURRED IN FEBRUARY AND MAY 1977.

Figure 12. Maximum (May) and minimum (February) tidal ranges for an 8-month monitoring period (January-August 1977)

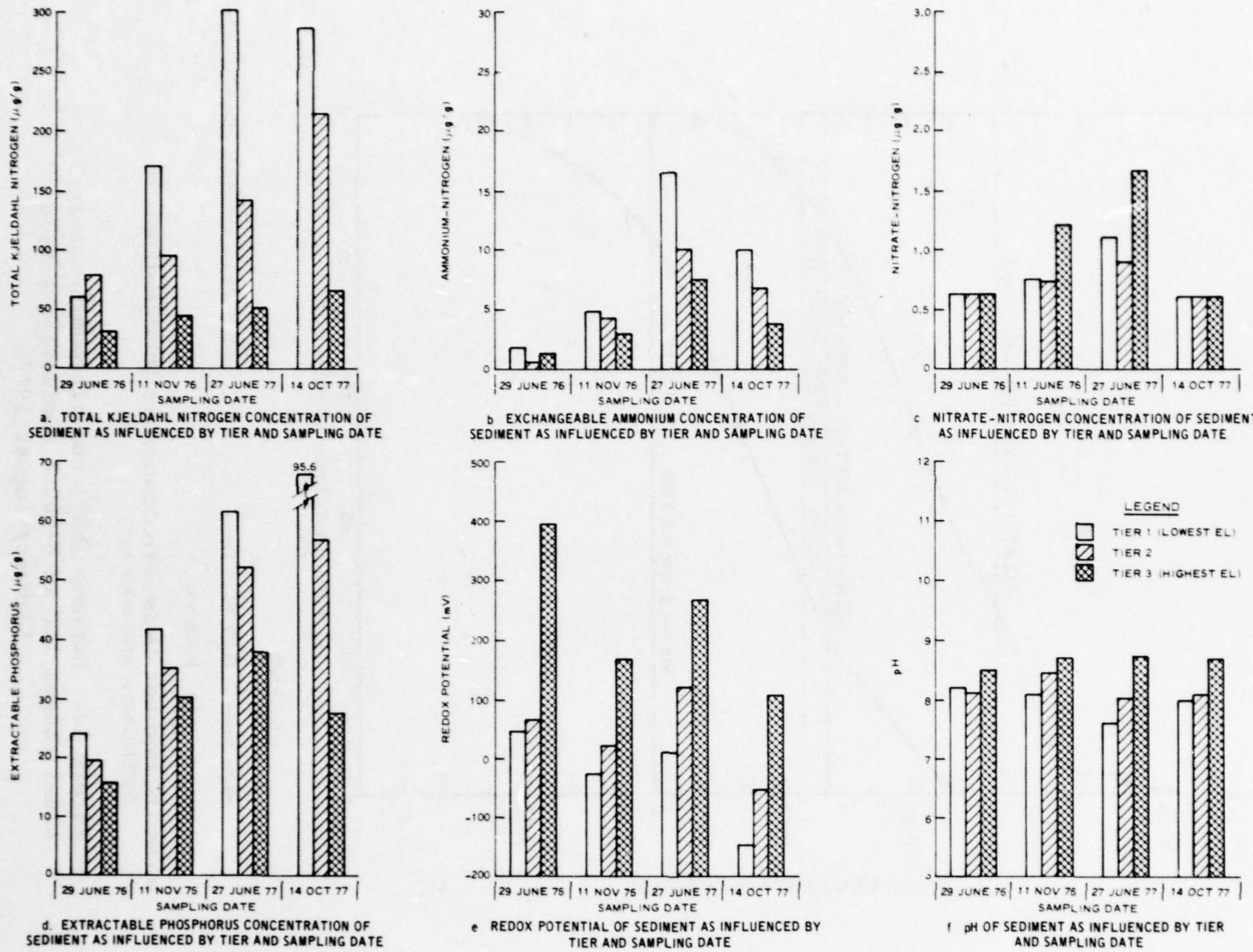
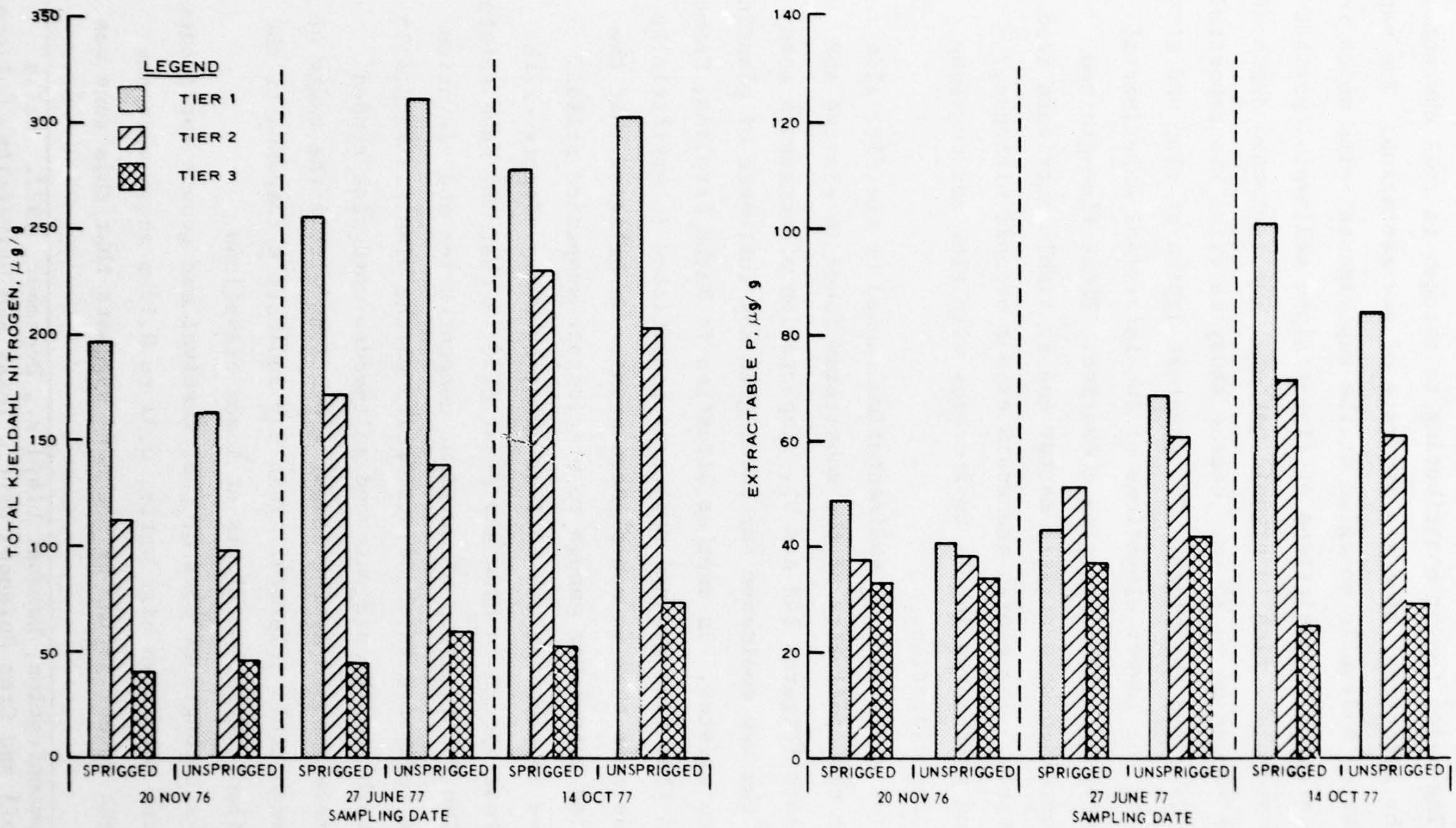


Figure 13. Comparisons of nutrient concentrations wih elevation (tier) and time



a. TOTAL KJELDAHL NITROGEN OF SEDIMENT AS INFLUENCED BY TIER, SAMPLING DATE AND PRESENCE OF SPRIGGED SMOOTH CORDGRASS

b. EXTRACTABLE PHOSPHORUS OF SEDIMENT AS INFUENCED BY TIER, SAMPLING DATE AND PRESENCE OF SPRIGGED SMOOTH CORDGRASS

Figure 14. Comparisons of nutrient concentrations with elevation (tier) and and time and among planted and unplanted plots

40. The major factor contributing to changes in soil characteristics of the intertidal zone was the rate of sedimentation. The sandbag dike lowered hydraulic energies at the experimental site which in turn led to greater accumulations of fine-grained sediments, particularly silts and clays rich in organic matter. The increased depth of new sediment ranged up to 15 cm. Coarse sandy material was deposited between the dike and the plots. The greatest depths of clay and silts accumulated in the lowest elevations of the intertidal experimental area and decreased with increasing elevation. These fine-grained sediments contained more organic matter and available nutrients than underlying sands. Therefore, one would expect organic nitrogen, ammonium, and phosphorus levels to increase with time and decrease with increasing elevation.

41. The rapid rate of sedimentation caused by the dike also accounts for the similarity of the substrates found in planted and unplanted plots (Figures 14a and b). Importation of nutrients associated with the new sediments far outweighed any influence of planting that may have existed. In another situation in North Carolina, Cammen (1976) found that fine-grained sediments accumulated in artificially planted areas more than in non-planted areas. He believed that the plants lowered turbulence enough to precipitate suspended solids. This may have happened at the Bolivar site; however, effects of the dike were great enough to hide any plant effects that may have existed.

42. The relationship of nutrient concentration and elevation tended to be reflected in the distribution of the plants. Figure 15 shows that both smooth cordgrass and saltmeadow cordgrass tended to produce more biomass at the lowest elevations within the range of elevations each could tolerate. This may indicate a response to the greater availability of nutrients at lower elevations.

43. An incongruous zone of poor survival and growth for plants became evident near mean high water, 0.37 to 0.52 m above mean sea level. Recent investigation by Hossner* suggests that this zone was

*Personal communication, Hossner Lloyd R., December, 1977. Soils Chemist, Soil and Crop Sciences Dept., Texas A&M University, College Station, Texas.

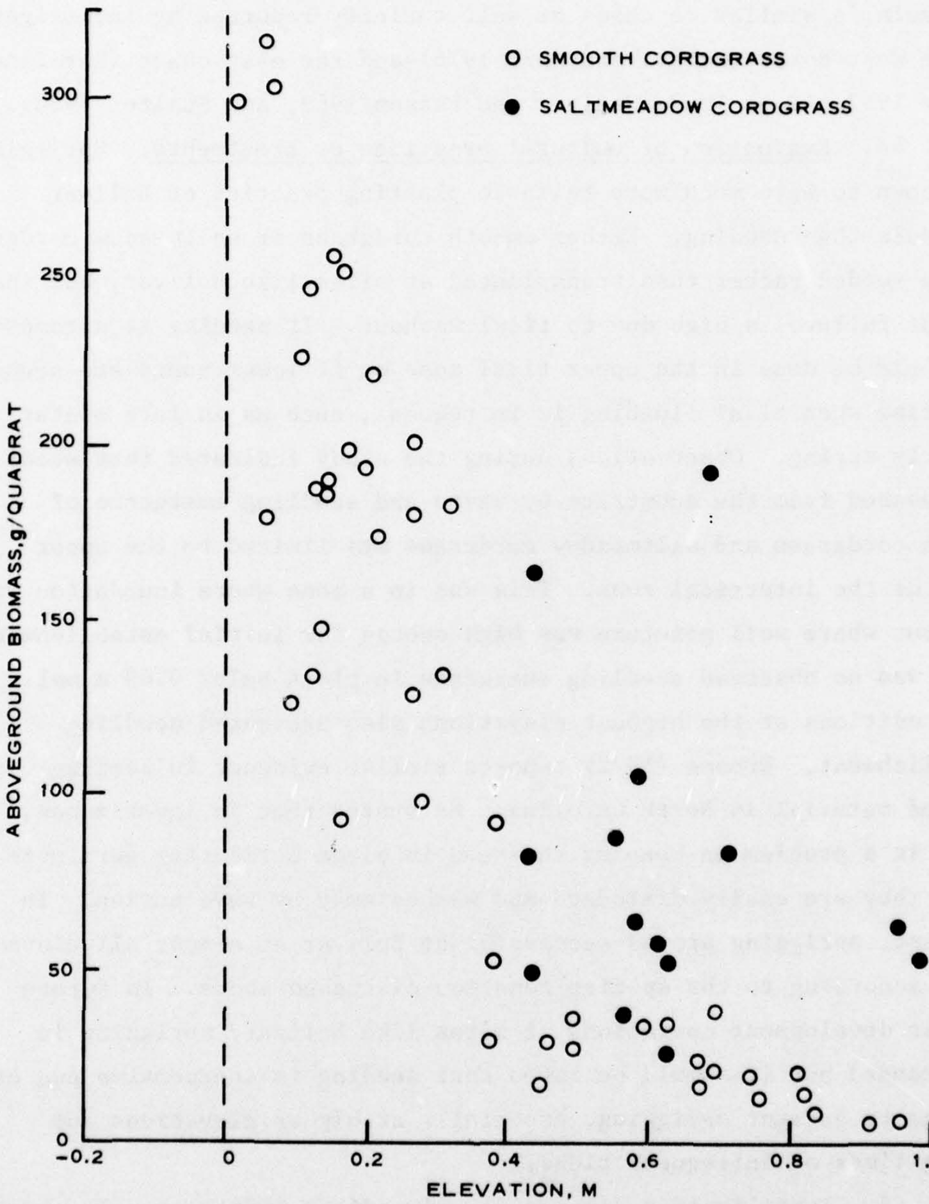


Figure 15. Relationship of plant productivity to elevation

caused by an accumulation of salt in the soil when the substrate remained above high tide for long periods and the evaporative concentration of salts exceeded leaching by rains. This observation at Bolivar Peninsula is similar to cases of salt toxicity reported by investigators on the west coast (Mahall and Park 1976) and the east coast (Kurz and Wagner 1957, Adams 1963, Stalter and Batson 1969, and Stalter 1973).

44. Evaluation of cultural practices or treatments. Sprigging was shown to be a much more reliable planting practice at Bolivar Peninsula than seeding. Either smooth cordgrass or saltmeadow cordgrass may be seeded rather than transplanted at sites like Bolivar, but the risk of failure is high due to tidal washout. If seeding is attempted, it should be done in the upper tidal zone or if lower zones are seeded, at a time when tidal flushing is infrequent, such as in late winter or early spring. Observations during the study indicated that seeds were washed from the substrate by waves and seedling emergence of smooth cordgrass and saltmeadow cordgrass was limited to the upper third of the intertidal zone. This was in a zone where inundation was rare but where soil moisture was high enough for initial establishment. There was no observed seedling emergence in plots below 0.43 m msl. Dry conditions at the highest elevations also prevented seedling establishment. Broome (1972) reports similar evidence in seeding dredged material in North Carolina. He states that in lower zones, there is a problem in keeping the seed in place until they germinate since they are easily dislodged and washed away by wave action. In contrast, sprigging proved successful at Bolivar at almost all elevations according to the species zonation discussed above. In future habitat development operations at sites like Bolivar, sprigging is recommended but it should be noted that seeding is inexpensive and can be used to augment sprigging, especially at higher elevations and during times of infrequent tides.

45. Fertilization did not clearly effect differences in marsh plant survival, vegetative reproduction, growth in height, or seed production of either plant species tested in intertidal experiments. The rapid rate of sedimentation and nutrient influx may have over-

shadowed any possible effects of fertilization. Therefore, initial fertilization did not seem worthwhile in the intertidal zone at the Bolivar site.

46. The sandbag dike was an effective wave stabilizer. Plantings in plots outside the diked area had lower survival and were in poorer condition throughout the study period than plantings within the diked area. Figure 16 illustrates the differences in response of plants within the dike versus those outside the dike. Plants within the dike are more dense and are darker in appearance indicating healthier stands of plants than those outside the dike. It is difficult to conclude that this difference was caused solely by the wave reducing effort of the dike, although this certainly would seem to be an important factor. It is also possible that the sedimentation and nutrient influx caused by the dike in the experimental area were the major reasons for the difference in plant performance. In either case, it seems unlikely to expect much success with marsh establishment in areas with excessively high wave energies unless energy is dissipated.

47. Successful sprigging attempts were achieved with both marsh species in both late winter and summer. However, late winter or early spring planting is recommended in the Texas gulf coast area for maximum recovery from planting shock and to insure maximum plant densities and growth by the end of the growing season.

48. Plant invasion. Plant invasion of the intertidal area by non-planted species was not a problem. The invasion that did occur was primarily by smooth cordgrass and saltmeadow cordgrass in the highest tier. The only invading plants observed in the lower two tiers were smooth cordgrass seedlings and tillers from already established plots. Minor invasion at the highest elevations did occur by the species mentioned below and which are listed in the order of number invading (greatest to least): seashore dropseed (*Sporobolus virginicus*), American bulrush (*Scirpus americanus*), fimbry (*Fimbristylis castaneum*), yellow nutgrass (*Cyperus esculentus*), salicornia (*Salicornia* spp.), and coastal bermuda. At elevations above mean high tide, invading species may include only local plants adapted to the marshland environment.

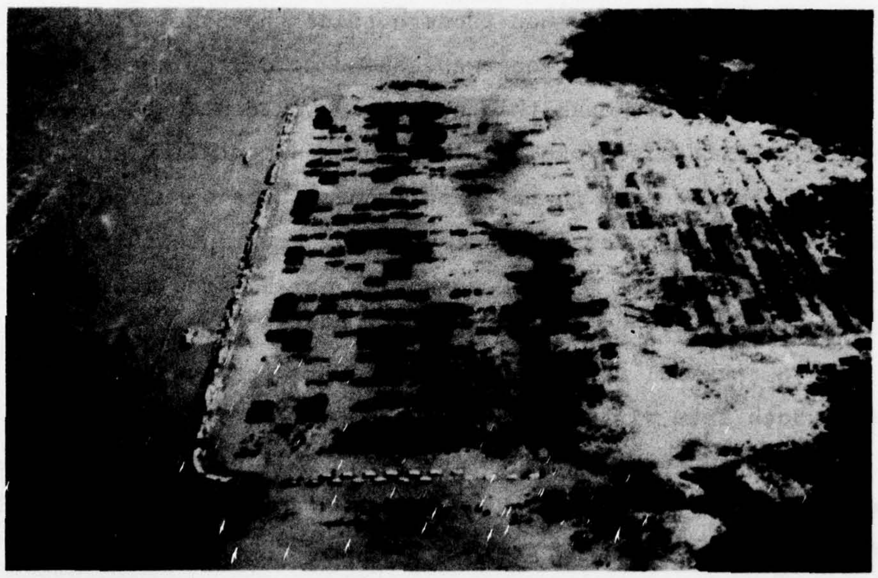


Figure 16. Plant response due to apparent lack of protection from waves by the dike. Note the denser and healthier plants inside the dike versus those outside

Upland Zone

49. Elevation. Variation in elevation, although not great, appeared to be related to the success or failure of most species planted in the upland. West side plots were about 0.15 m lower than east side plots and were low enough to be exposed to tides and frequently flooded or wet soils. Plants that performed poorly in low, wet soils included coastal bermuda grass, bitter panic grass and gulf croton. In contrast, salt cedar and sand pine performed poorly on the higher dry soils. The most tolerant of variation in elevation and moisture were live oak, winged sumac and wax myrtle. The bluestem transplants performed poorly over the entire site even though they grew naturally in the surrounding area. Transplanting might be a poor method of propagating bluestem whereas seeding might be better, but this needs further experimentation. The percentages of plants surviving during a 9- to 15-month period were:

Species	Average Survival, %
bluestem grass*	5.4
coastal bermuda grass*	81.3
bitter panic grass*	84.7
salt cedar**	28.4
sand pine**	31.9
live oak**	96.5
winged sumac**	66.0
gulf croton**	22.2
wax myrtle**	62.9

*Evaluated on 22 June 1977

**Evaluated on 26 September 1977

50. Fertilization. Coastal bermuda and bitter panic grasses grew better when fertilized but fertilization had no effect on their survival. Plant growth, density, and other performance factors for both grasses greatly increased with repeated applications of fertilizer.

51. The survival of wax myrtle and the growth in height of sand pine were increased by fertilization, but no other fertilizer effects were observed among the other trees and shrubs. The influence of elevational variation may have overshadowed the effects of fertilization on other species. As Webb et al. (1978) noted, the effects of fertilization on plant performance may not be noticeable in trees and shrubs for several years; therefore, the long-term fertilizer effects in this situation are unknown. Tentatively, the planting success of most species was not diminished and for some species it may be improved by fertilizing upland, sandy, dredged material.

52. Plant invasion. Greatest invasion occurred at intermediate elevations in the upland by such species as yellow nut grass, American bulrush, western ragweed (*Ambrosia psilostachya*), Drummond sesbania, seashore dropseed, and saltmeadow cordgrass. Extremely wet or dry conditions of plots appeared to inhibit invasion. Invasion was more noticeable in fertilized than unfertilized plots. Invaders were more prevalent in plots of trees and shrubs that were less dense and had less ground cover. In fact, all but the unplanted plots in the trees and shrubs were weeded to eliminate competition by Drummond sesbania since the objective was to evaluate the survival of plants and their response to fertilization without outside variables. However, the evaluation of invaders was facilitated by the monitoring of unplanted plots. The plots planted to coastal bermuda and bitter panicum did not receive much invasion, probably because invaders could not get started in the dense ground cover of the two grasses.

53. Weeding was essential for this study, at least in the plots planted to trees and shrubs. For future habitat development the decision to weed or not to weed must be made in light of the value of target plant species wished to be developed versus the value of the invading plants. On this site, the target plant species were considered to have more experimental and wildlife value than the invading plants. If the invading plants had been allowed to grow unchecked, they probably would have jeopardized the survival of the plants being developed.

Summary and Conclusions

54. This study indicates that smooth cordgrass and saltmeadow cordgrass can be artificially established in an intertidal zone on dredged material, but particular attention needs to be given to elevational variation. Elevational gradients within the intertidal zone determine the amount and periodicity of inundation which, in turn, affect the sedimentation rate and availability of nutrients associated with the new sediments, the accumulation of salts in the substrate, and the germination and survival of seeds. Although smooth cordgrass can be transplanted successfully at Bolivar Peninsula over most of the intertidal zone, it grows best below mean high water. In contrast, saltmeadow cordgrass survives and grows best in periodically inundated areas above mean high water. Either species may be seeded rather than transplanted but the risk of failure is high because of seed washout by tidal waters. Fertilization does not appear to significantly affect growth in the intertidal zone.

55. Planting upland areas with grasses, shrubs, and trees was partially successful, depending on the species and the variation of soil moisture in the experimental area. Species that generally performed best were coastal bermuda grass, bitter panic grass, live oak, winged sumac and wax myrtle. Sand pine, gulf croton and salt cedar might be suitable in areas where their soil-moisture requirements are likely to be more uniformly met. Plant invasion was a problem in the plots planted to trees and shrubs. Except for the unplanted plots in the tree and shrub areas, invaders were removed. For future habitat development efforts in this area, it is recommended that weeding be done until the planted species are established.

PART V: AQUATIC BIOLOGY

Methods and Materials

56. Studies in aquatic biology were undertaken to assess the environmental impacts that habitat development would have on fish and benthic invertebrates. The effects of habitat development were assessed through interpretation of patterns in the composition, feeding habits, and resource value of the aquatic animals in the vicinity of the experimental area. A baseline survey was conducted from March to October 1975 to provide an inventory and assessment of fish and benthos prior to site construction. After construction of the site a second study was conducted from July 1976 to June 1977, to document changes associated with the habitat development.*

57. For the baseline study, fish and crabs were collected only during the day in intertidal areas using a 15-m bar seine with a 13-mm stretch mesh and a 1.8-m beam trawl with a 1.3-m wide body of 0.47-mm mesh. Subtidal areas were sampled with a 3-m wide, flat, shrimp trawl of 25-mm stretch mesh. A 0.025-m^2 Eckman grab was used to take macrobenthic invertebrate samples, which were washed through a 500-μm sieve. Macrobenthos were functionally defined as the invertebrates retained on the 500-μm sieve. Samples were taken in both intertidal and subtidal areas within and on either side of the location initially proposed for habitat development (Figure 17).

58. After the new habitat was constructed and planted, fish samples were taken day and night inside and outside of the diked area with the following sampling devices: 7.62-m beach seine of 6.35-mm mesh; 1.5-m wide push net with 4.7-mm mesh; 0.9-m diameter hoop net having 25.4-mm bar mesh; and standard minnow traps. Also during this period, feeding habits were determined for selected fish species. Processing and analysis of fish stomachs followed methods described by

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* As noted earlier in the Introduction of this report, the site was moved 305 m to the east after most baseline samples were made.

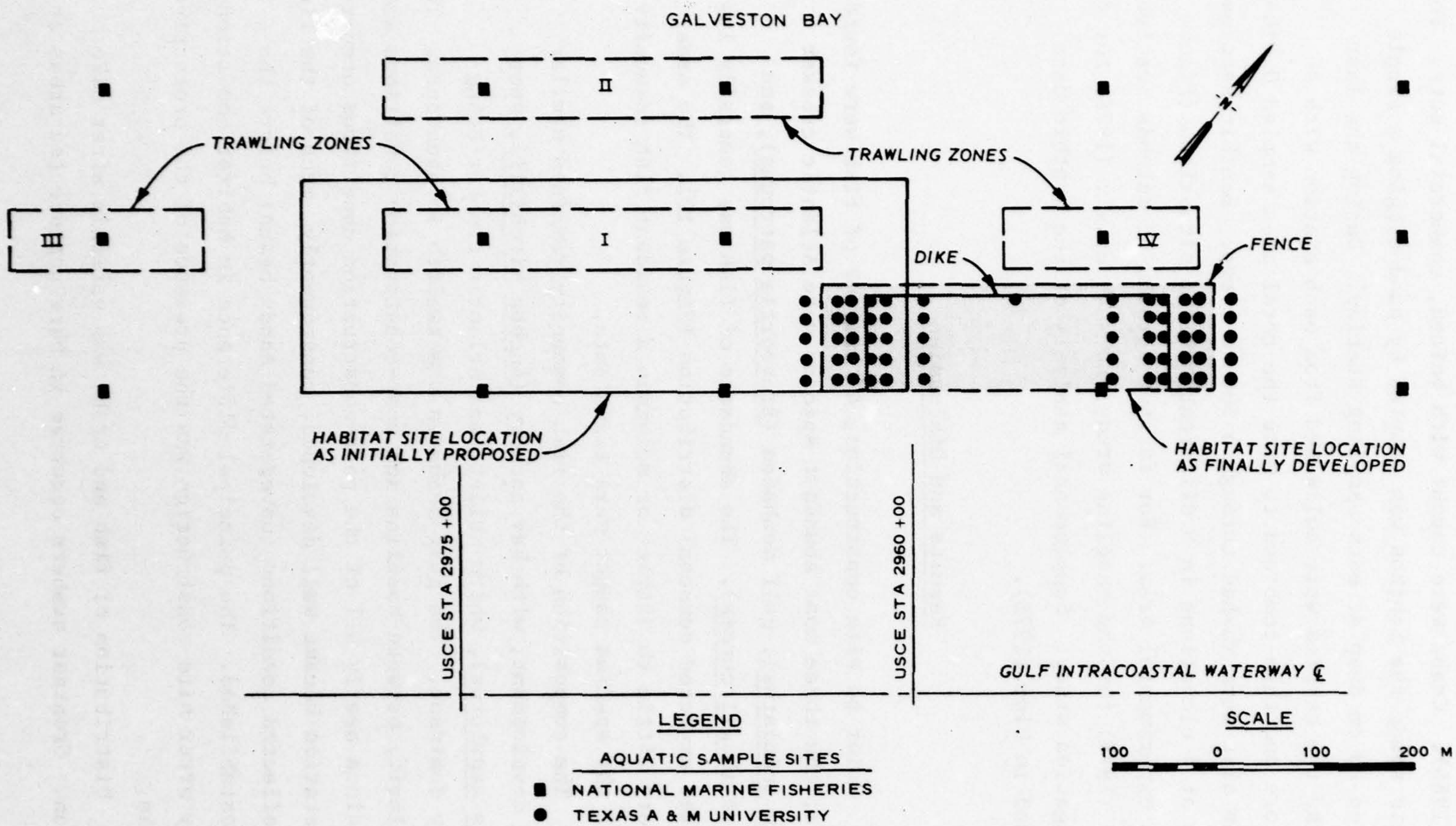

Figure 17. Locations of preconstruction samples collected by the National Marine Fisheries Service and postconstruction samples collected by Texas A&M University

Borgeson (1966). Crabs were caught with baited, commercial pots. For most of this study the benthos was sampled by hand-digging a single 0.05-m^2 area 20 cm deep at each sampling station. During the last three months two samples were collected from each station with a 0.008-m^2 core and then combined to make the total area sampled 0.016-m^2. The samples also were washed through a 500-μm sieve. Benthic samples were taken at 5 elevations in 6 different habitat situations (Figure 18) within the experimental area. For further details of methods see Lyon and Baxter (1978) for the baseline study and Webb et al. (1978) for the post-propagation study. Supplemental analysis of the benthic data can be found in Diaz (1978).

Results and Discussion

59. Prior to site construction, 47 species of fish were found in the area; the three most abundant species were Atlantic croaker (*Micropogon undulatus*), gulf menhaden (*Brevoortia patronus*), and white mullet (*Mugil curema*). The abundance of fish was generally low but reflected expected seasonal distribution (Figure 19). The area provided very little to attract or maintain a resident fish community and most of the species caught were transients.

60. The composition of the fish community remained similar after site development, with bay anchovy (*Anchoa mitchilli*), spot (*Leiostomus xanthurus*), white mullet, and Atlantic croaker being numerically dominant. The gulf menhaden was twelfth in abundance. The great similarity between baseline and post-construction conditions was expected, since nearly all of the post-construction conditions occurred before vegetation became well developed; consequently, much of the field sampling reflected conditions (unvegetated sandy beach) before the marsh was established. The principal difference in habitat conditions immediately after site construction was the presence of the protective sandbag dike.

61. Distribution of fish and crabs was variable after dike construction. Greatest numbers occurred in bare unprotected areas at

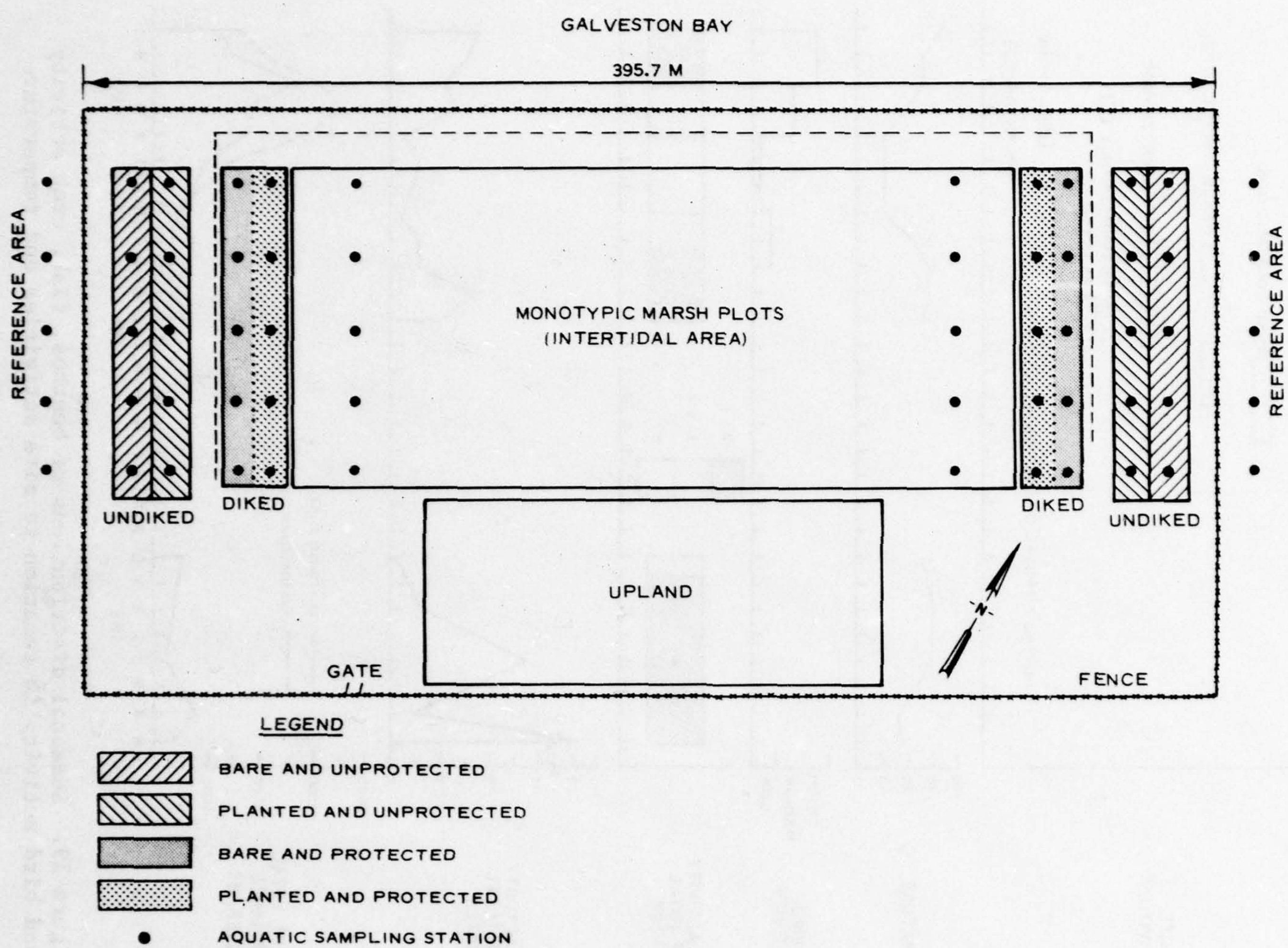

Figure 18. Habitat types and locations of aquatic samples collected after site construction

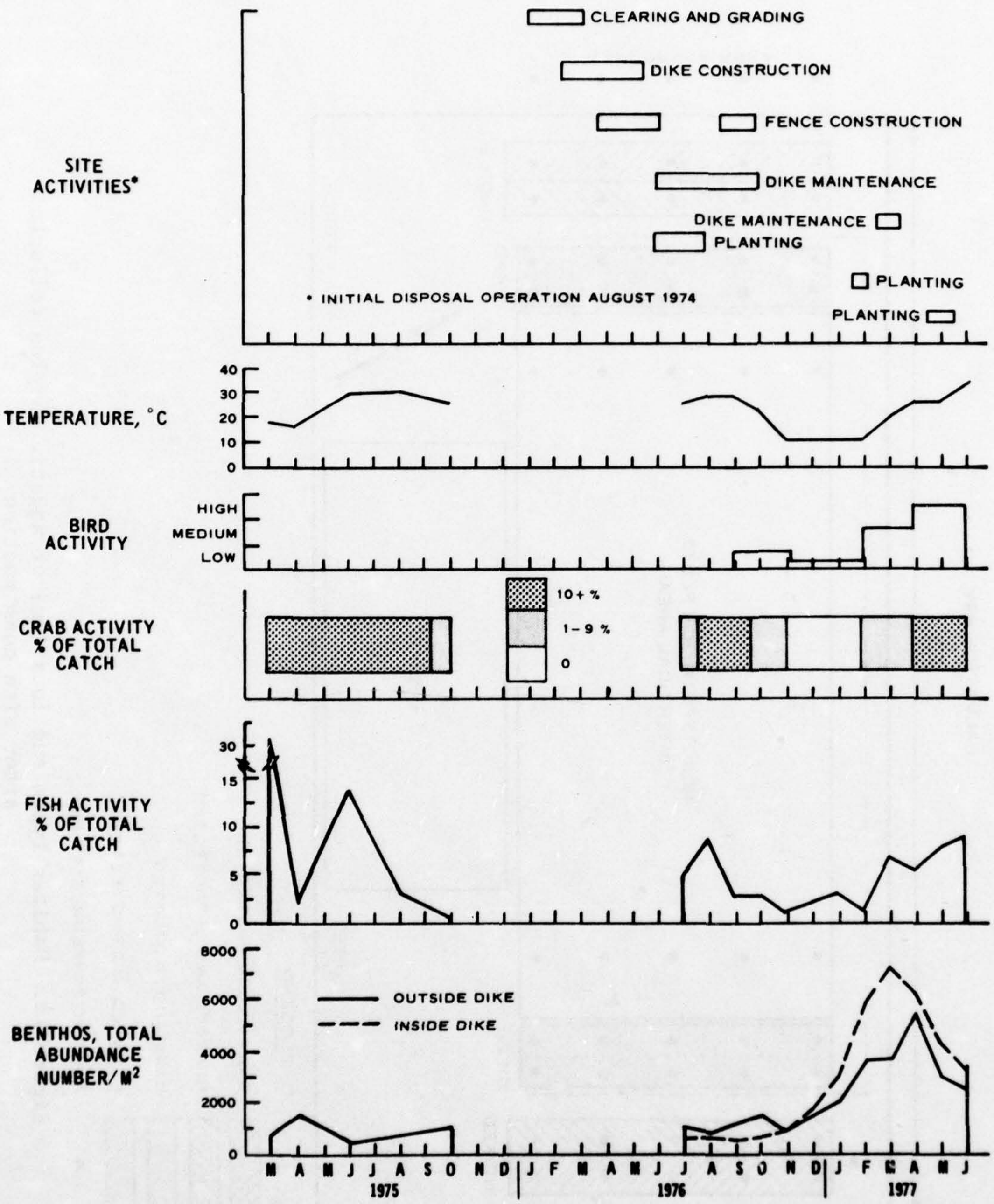

Figure 19. Seasonal distributions of benthos, fish, crab activity, and bird activity in relation to site activities and temperature

night. Catch in bare protected areas was similar to bare areas outside the fence which are identified as reference areas in Figure 18. Sampling within the planted marsh yielded very few individuals. These low numbers may be more a reflection of the sampling gear's inability to catch fish in vegetated areas than of the scarcity of fish since many fish were frequently observed in the planted areas. Species diversity of fish was highest in the reference and bare unprotected areas and lowest within the dike. However, the establishment of the dike seemed to break the otherwise homogeneous environment and attract fish to its more accessible outer edge.

62. The fish studies did not firmly indicate that new habitat was used more than the existing bare area, but as the marsh develops further, the use by fish is expected to increase. A comparison of the fish catch in July 1976 before plant establishment, and June 1977 indicates a slight increase in abundance (Figure 19).

63. The benthic invertebrates that colonized the dredged material were well adapted to the rigorous environment at the site, which is characterized by exposure to waves, high summer temperatures, and strong wind-tides. By March 1975, seven months after the disposal operation, the site had been invaded by the major groups of animals normally associated with sandy substrates in the area. The dominant ones consisted of polychaete worms, an anthurid isopod, and haustorid amphipods. The changes in the abundance of zooplankton, which also provide food for juvenile fish, were generally similar to changes in benthic abundance. The abundance of benthos increased through spring and early summer but declined sharply during midsummer. These changes in relative abundance most likely were caused by a combination of warming temperatures and increased predation by fish and crabs. Water temperatures in July reached 30 deg C in the shallow water that covered the site. Two of the most abundant fish caught at the site, Atlantic croaker and spot, depend greatly on benthos as a primary food source, as does the blue crab (Callinectes sapidus). As the abundance of fish and crab and the temperature declined in the late summer and fall, the benthos began to become more numerous (Figure 19).

64. It is difficult to assess the acute impacts of construction and site preparation on the benthos. There was a slight increase in benthic abundance between the summers of 1975 and 1976. However, this increase probably reflected the additional year the benthos had to populate the original dredged material rather than the effect of construction. The benthos were more abundant outside the sandbag dike than inside the dike from July to October 1976. Within the dike, abundance was most reduced in the planted areas where the most intense site modifications occurred during site preparation. By November, four months after the start of construction, benthic abundance was similar inside and outside the diked area. Despite the similarity in abundance values, the species composition of the benthic communities within and outside the diked area remained different. Inside the diked area, there was a reduction in the species most sensitive to disburbances, such as the anthurid isopod, while less sensitive species, mainly polychaete worms, maintained or increased their abundance.

65. The protected area behind the dike accumulated fine sediment with time. One year after the dike was built there was a thin layer of fine sediment on top of the well-sorted, sandy dredged material. The average thickness of this layer varied from less than 1 cm at the high intertidal areas to 15 cm in low tidal areas along the western side of the habitat.

66. The benthos responded to the changing sedimentary environment with a general increase in species that associate with fine sediments, mainly polychaete and oligochaete worms. Also, as the plants developed, the numbers of shore insects, mainly dipterans and beetles, increased greatly in the study area. Insects were very abundant by the spring of 1977, especially in the planted parts of the higher intertidal zone. The plants also increased habitat diversity for the benthos and shaded the sediment surface from extreme summer heat. The abundance of benthos in the spring and summer following dike construction and planting was 1.5 times greater inside the diked area than in the surrounding vicinity, and within the dike the benthos in planted areas was 1.5 times as abundant as the benthos in bare areas.

67. Fish, crabs, and birds, the main predators on the benthos, used the area heavily in spring and summer and benthic abundance declined from a late-winter high as the abundance of predators peaked. The greatest decline occurred in areas that seemed most accessible to predators, mostly the bare areas within the dike where the highest standing stocks of benthos had developed before fish moved into the area. Benthic abundance changed less from winter to summer in the planted areas, possibly because plants protected the benthos from predation and excessive temperatures.

68. The stomach contents of the most abundant fish indicated that both macrobenthos and meiobenthos were included in their diets. Smaller fish seemed to prefer meiobenthic harpacticoid copepods and larger fish preferred the macrobenthic polychaetes and isopods. Polychaete abundance was highest within the diked area while isopod abundance was highest in areas farthest from the dikes. The smaller meiobenthos were not censused concomitantly with the macrobenthos, but qualitative observations indicated the nematodes, harpacticoid copepods and ostracods were the most common major groups.

Summary and Conclusions

69. The fish communities in the study area before and after habitat development were similar with respect to species composition and relative abundance. This similarity may have occurred because of the delayed development of planted areas. The sandbag dike provided habitat diversity that may have attracted some fish in the otherwise homogeneous beach environment of Bolivar Peninsula. As the marsh within the diked area develops further, there should be more use by those fish species that frequent and depend upon marshes, such as killifishes and small minnows. During the beginning of the second growing season in June 1977, the site already provided heterogeneous habitats which tended to support greater use by fish and benthos than is generally associated with sandy shores along Bolivar Peninsula.

70. Increased protection from waves and subsequent entrapment of fine sediments by the dike accounted for much of the increased benthic abundance within the diked area. The presence of plants seemed to attract more insects. One year after construction the experimental habitat supported greater abundances of polychaetes and insects than the surrounding area. The abundance of isopods on the other hand, was much less within the diked area than outside. Polychaetes and isopods, along with harpacticoid copepods, were among the most important food items found in the stomachs of abundant fishes. The experimental habitat has the potential for providing greater trophic values and protection for valuable fish and wildlife than previously existed in the area.

PART VI: WILDLIFE

Methods and Materials

71. Bird, mammal, reptile, and amphibian use of the Bolivar Peninsula Habitat Development Site was examined between July 1976 and November 1977, with the objective of describing wildlife response to site development. The site initially chosen for habitat development was surveyed between September 1975 and March 1976 for baseline data.*

72. Baseline observations of wildlife composition and abundance were made using the methods described below. Bird species and abundance were recorded along transects sampled once a month. Presence of mammals was determined by use of monthly trapping sessions. Other vertebrates were identified by sightings and sign and terrestrial macroinvertebrates were collected by use of a sweep-net and household pesticide.

73. Vertebrates on the actual habitat development site were observed between July 1976 and November 1977. This represented an experimental period after site construction (grading, sandbag dike construction, fencing) and planting activities were almost or totally complete. Bird species and abundance were estimated twice a month from observation stations on transects traversing the intertidal and upland experimental areas and adjacent natural marsh and upland habitats (Figure 20). Bird population density and species diversity were determined by standard methods. Bird nesting was observed and recorded from nest searches during March through June 1977. Small mammals were live-trapped on grids in the upland experimental area and two adjacent natural areas outside the fence between September 1976 and August 1977. Large mammals were caught in live traps that were irregularly placed over the experimental area; they also were observed and/or recorded through sightings and identification of sign. Species of reptiles and amphibians were recorded when sighted. Further details of the methods

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* As noted earlier in the Introduction, the site was moved 305 m to the east after baseline samples were made.

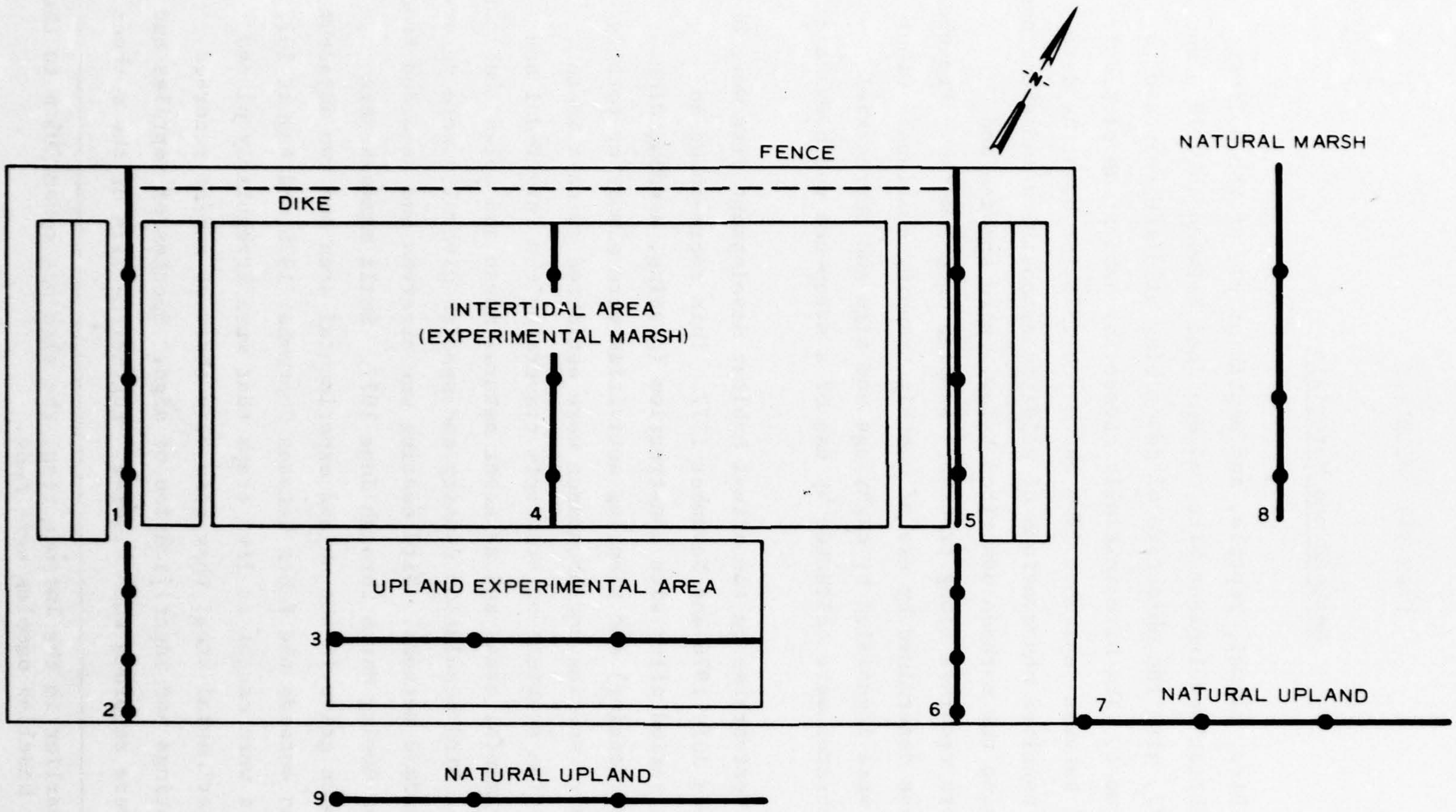

Figure 20. Location of bird transects in the experimental and natural areas, with observation stations indicated (●). Transects 2 and 6 were eliminated in March 1977

and locations of baseline areas and transects can be found in Dodd et al. (1978) for the baseline period and in Webb et al. (1978) for the experimental period.

Results and Discussion

Birds

74. The baseline study area yielded 98 species of birds. Permanent and wintering species were nearly equally represented (34 and 35, respectively) while there were only 20 migrants and 9 summer residents. Diversity was high, ranging from 2.81 in December 1975 to 3.98 in September 1975. Average number of species on the shoreline and marsh transects was 20.8 while 16.8 were represented on the upland transects. All the above results would undoubtedly have been modified if sampling had been performed over a twelve-month period.

75. Seventeen months of sampling on the actual study area yielded 135 bird species (Table 4). There were 71 species in common from the baseline area and the actual study area. Thirty-seven of the 135 bird species or 27.4 percent were migrants and recorded only in the spring; they contributed to the high densities and diversities recorded for that season (Figure 21). Data from summer and winter seasons showed lower numbers. Lowest diversity as expected, due to little vegetative cover, was observed in the fall of 1976.

76. Species numbers were consistently higher in the experimental marsh than in the natural marsh, but density was consistently less. There were no obvious trends in the upland areas. Thirteen species were recorded in densities greater than 3.00/ha including 11 species of shorebirds, laughing gulls, and red-winged blackbirds.

77. The least tern (*Sterna albifrons*) was the most prolific of the six species nesting on the study area in 1977, with 23 nests in the upland and four in the marsh sections, a density of 9.8/ha. Nest success was 61.5 percent based on 13 nests with complete data, and egg success was 65 percent, based on the known fate of 20 eggs. Clutch size averaged 1.74 with a total of 47 eggs. Hatching successes of

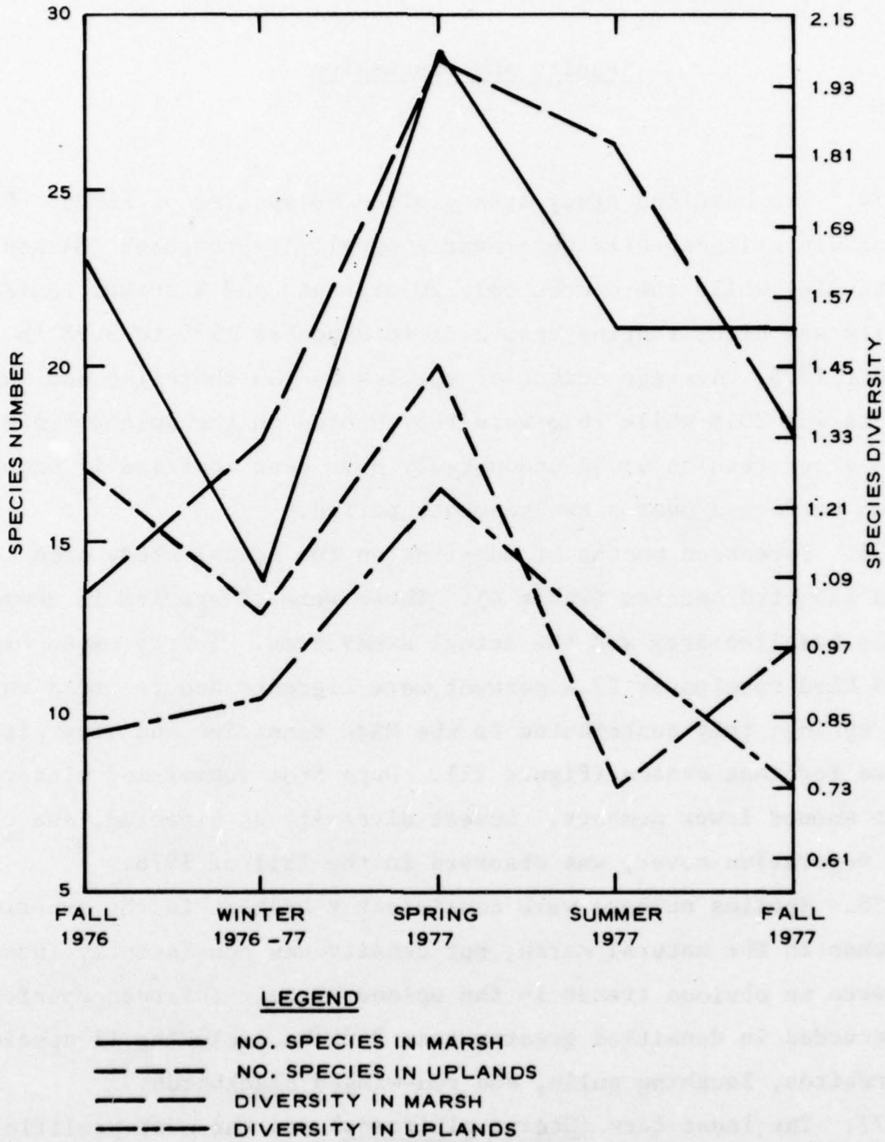

Figure 21. Bird species number and diversity, by season, for marsh and upland transects

79.2 percent and 56.3 percent were reported for the California least tern (Sterna albifrons browni) (Massey 1971, Swickard 1974). Nest success of terns in the experimental area is largely attributed to the fence, which excludes most predators and goats. A search of suitable habitat outside the fence revealed only one active nest (Webb et al. 1978).

78. Other species that nested in the experimental upland were Wilson's plover (Charadrius wilsonia) and killdeer (C. vociferus); in the experimental marsh, the brown-headed cowbird (Molothrus ater) and red-winged blackbird nested. No nests were found in adjacent natural marshes. The natural upland area had one nest of the scissor-tailed flycatcher (Muscivora forficata), and two each of the red-winged blackbird and brown-headed cowbird.

Mammals

79. Seventeen species were recorded during the baseline and experimental periods between September 1975 and September 1977 (Table 5). The fence prevented or discouraged five of those seventeen species from entering the experimental site.

80. Vegetation planted during the study appeared to attract three species. Eastern cottontails (Sylvilagus floridanus) were seen on the site in July 1976 and during almost all visits from January through August 1977. They grazed on both species of newly planted marsh grasses causing only slight permanent damage. When vegetation on the experimental site had become dense and tall enough to provide cover in the summer of 1977, the marsh rice rat (Oryzomys palustris) and hispid cotton rat (Sigmodon hispidus) were trapped for the first time. The cotton rat and the rice rat had been captured outside the fenced area since September 1976 and February 1977, respectively. One rice rat nest was found in the planted smooth cordgrass in July 1977.

81. The cotton rat was trapped heavily (88 individuals) outside the fenced area, with a tendency toward lower numbers in the winter and spring. This seasonal fluctuation has been recorded by Odum (1955) in Georgia, Layne (1974) in Florida, and Lee (1976) on Bolivar Peninsula.

Cotton rat presence also appeared to be related to availability of cover since the lowest number of captures (two) was made in February 1977, when cover was least. Both this observation and the sudden movement of the cotton rat into the vegetation of the fenced area agree with the work of Goertz (1964), who discussed the necessity of cover for the cotton rat. Details of cotton rat and house mouse (Mus musculus) populations from the baseline area and their reproductive states are given in Lee (1976).

Reptiles and amphibians

82. Fourteen species of reptiles and amphibians were sighted during the baseline and experimental periods between September 1975 and March 1977. Sightings declined during the experimental period, probably because of increased human activity. All reptiles and amphibians seen in the experimental site were in the upland area. Species lists can be found in Dodd et al. (1978) and Webb et al. (1978).

Summary and Conclusions

83. Wildlife use of the experimental site increased over the period of the study in response to growth of vegetation. This use was most obvious in the marsh. Shorebirds associated with marshes moved onto the site and increased in density, and two species of wetland-related mammals colonized the site. Seasonal variation in bird use was especially evident in the numbers of spring migrants recorded.

PART VII: OVERALL CONCLUSIONS AND RECOMMENDATIONS

84. Successful plantings of marsh grasses and upland plants were made at Bolivar Peninsula during 1976 and 1977. Even though the plants are still young and the site is not fully developed, results indicate that plants are providing habitat that is attracting fish and wildlife. Thus, habitat development on dredged material at Bolivar Peninsula is feasible. The investigation led to several salient conclusions and recommendations which are discussed below.

<u>a</u>. Habitat was developed at Bolivar Peninsula by providing protection to plants from physical forces such as wind and waves and protection from large animals such as goats. It is recommended that alternatives other than a sandbag dike be considered for cost effective, but satisfactory means of protecting a planted site from wind and waves in high energy areas, such as Bolivar Peninsula. Where practical, dredged material should be used to form a protective barrier for areas with intense wave energies. Fences should be constructed to protect the site if large grazing animals are present.

<u>b</u>. Results of this study indicated that smooth cordgrass and saltmeadow cordgrass are good marsh plants for marsh habitat development on dredged material in the Texas gulf coast area. Elevation was probably the most important factor at Bolivar Peninsula in determining the success of marsh grasses. In future habitat development efforts in this area, smooth cordgrass should be sprigged at elevations below mean high tide whereas saltmeadow cordgrass should be sprigged at elevations above mean high tide. Seeding should be used only to augment sprigging and fertilization does not appear necessary.

<u>c</u>. Several upland plant species of grasses, shrubs, and trees survived from plantings at Bolivar Peninsula. Plants appearing to have good survival and growth potential on upland dredged material sites in the Texas gulf coast area are: live oak, winged sumac, wax myrtle, bitter panic grass, and coastal bermuda grass. Results from this study tentatively indicate that fertilization of upland plants generally has a beneficial effect on planting success; however, observations over a longer time period are needed to confirm this effect.

d. Termination of the project eliminated observations of aquatic biota at a time when the marsh was just becoming developed. Preliminary observations indicate that marsh development is associated with increases in benthic organisms as well as increases in insect and fish activity. Bird diversity and activity in the planted marsh also have increased. Thus, the developing habitat started by planting marsh grasses is likely to provide an area of greater resource value to fish and wildlife than previously existed on the sandy dredged material. Limited observations will be made in the future to document the expected increase in the use of the marsh by birds and aquatic organisms.

e. The plants in the upland habitat area, like the plants in the marsh area are young and have not achieved their full potential for providing food and cover for wildlife. However, the important point is that these plants have survived and are spreading. The upland area has already received nesting activity from five breeding bird species in the area and is expected to attract even more bird activity as well as more individuals and species of small mammals. If the fence were removed, larger mammals such as the raccoon, swamp rabbit, and opossum probably would use the site, but trampling and grazing by goats would jeopardize the successful development of the plants. The fence has caused some animals to seek the site's protection. For example, least terns have used the sight for nesting as opposed to areas outside the fence.

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Table 1

Project Costs

Cost Category	Approximate Unit Costs	Total
I. Plans and Specifications for Site Acquisition and Construction		
A. Topographic surveys		$ 7,000.00
B. Soil sampling and testing		22,000.00
C. Site layout, dike design, and other pre-development operations		14,700.00
D. Site acquisition		1,300.00
TOTAL		$ 45,000.00
II. Site Construction and Post-Construction		
A. Earthmoving, grading and other land preparation activities	$7,967/ha	$ 58,033.00
B. Sand bag construction and maintenance	$ 348/m	184,900.00
C. Fence construction	$ 16/m	19,052.00
D. Other costs (mobilization, demobilization, logistical support, dike and topographic surveys)		26,000.00
TOTAL		$287,985.00
GRAND TOTAL		$332,985.00

Table 2

Fertilizer Treatments Applied to the Thirty Plots within One Elevation Block of the Intertidal Monotypic Plot Experiment

Plot No.	Fertilizer Treatment*	Species	Method**
1	F_0	smooth cordgrass	sprig
2	F_0	smooth cordgrass	seed
3	F_0	saltmeadow cordgrass	sprig
4	F_0	saltmeadow cordgrass	seed
5	F_0	no planting	none
6	F_0	no planting	none
7	F_1	smooth cordgrass	sprig
8	F_1	smooth cordgrass	seed
9	F_1	saltmeadow cordgrass	sprig
10	F_1	saltmeadow cordgrass	seed
11	F_1	no planting	none
12	F_1	no planting	none
13	F_2	smooth cordgrass	sprig
14	F_2	smooth cordgrass	seed
15	F_2	saltmeadow cordgrass	sprig
16	F_2	saltmeadow cordgrass	seed
17	F_2	no planting	none
18	F_2	no planting	none

(Continued)

* The types of fertilizer treatment were:

F_0: no fertilizer

F_1: low rate, 122 kg N/ha, 122 kg P_2O_5/ha, and 122 kg K_2O/ha (122 g/m^2)

F_2: high rate, 244 kg N/ha, 244 kg/P_2O_5/ha, and 244 kg K_2O/ha (244 g/m^2)

F_3: split application, low rate

F_4: split application, high rate

** Seeding was accomplished in March 1977 on 30 sq m plots.

Table 2 (Concluded)

Plot No.	Fertilizer Treatment*	Species	Method**
19	F_3	smooth cordgrass	sprig
20	F_3	smooth cordgrass	seed
21	F_3	saltmeadow cordgrass	sprig
22	F_3	saltmeadow cordgrass	seed
23	F_3	no planting	none
24	F_3	no planting	none
25	F_4	smooth cordgrass	sprig
26	F_4	smooth cordgrass	seed
27	F_4	saltmeadow cordgrass	sprig
28	F_4	saltmeadow cordgrass	seed
29	F_4	no planting	none
30	F_4	no planting	none

Table 3

Fertilizer Treatment Design for Upland Experiments

Plant Type and Tier	Row	Species	Random Fertilizer Treatment of Subplots* Replicate 1			Replicate 2			Replicate 3		
Grasses, lower tier	1	bitter panicum	F_0	F_1	F_2	F_1	F_2	F_0	F_2	F_0	F_1
	2	coastal bermuda	F_1	F_2	F_0	F_2	F_0	F_1	F_1	F_2	F_0
	3	bluestem	F_2	F_0	F_1	F_0	F_1	F_2	F_0	F_1	F_2
	4	No planting	F_1	F_2	F_0	F_0	F_2	F_1	F_2	F_0	F_1
Shrubs, middle tier	1	gulf croton	F_1	F_2	F_0	F_0	F_1	F_2	F_2	F_1	F_0
	2	wax myrtle	F_0	F_1	F_2	F_2	F_1	F_0	F_2	F_0	F_1
	3	winged sumac	F_0	F_1	F_2	F_0	F_2	F_1	F_1	F_0	F_2
	4	No planting	F_2	F_0	F_1	F_1	F_0	F_2	F_0	F_2	F_1
Trees, upper tier	1	salt cedar	F_2	F_1	F_0	F_1	F_0	F_2	F_1	F_2	F_0
	2	No planting	F_1	F_2	F_0	F_0	F_2	F_1	F_1	F_0	F_2
	3	sand pine	F_0	F_1	F_2	F_1	F_2	F_0	F_0	F_1	F_2
	4	live oak	F_0	F_2	F_1	F_2	F_1	F_0	F_2	F_0	F_1

* Treatments consisted of: F_0 - no fertilizer applied;

F_1 - low rate, 25 kg N/ha applied initially with 50 kg P_2O_5/ha, and 40 kg K_2O/ha, 100 kg N/ha applied 1 month later;

F_2 - high rate,25 kg N/ha applied initially with 100 kg P_2O_5/ha, and 80 kg K_2O/ha, 200 kg N/ha applied 1 month later;

Table 4

Seasonal Occurrence of Birds at Bolivar Peninsula

Common Name	Scientific Name	Occurrence By Season				
		Fall 76	Winter 76-7	Spring 77	Summer 77	Fall 77
Eared grebe	*Podiceps nigricollis*			X		
White pelican	*Pelecanus erythrorhynchos*	X		X		
Double-crested cormorant	*Phalacrocorax auritus*	X				X
Olivaceous cormorant	*Phalacrocorax olivaceus*				X	X
Magnificant frigatebird	*Fregata magnificens*	X			X	
Great blue heron	*Ardea herodias*	X	X	X		X
Green heron	*Butorides striatus*			X		
Cattle egret	*Bubulcus ibis*			X		
Reddish egret	*Dichromanassa rufescens*	X	X	X		X
Great egret	*Casmerodius albus*	X	X	X	X	X
Snowy egret	*Egretta thula*	X	X	X	X	X
Louisiana heron	*Hydranassa tricolor*	X		X	X	X
Black-crowned night heron	*Nycticorax nycticorax*	X				
White-faced ibis	*Plegadis chihi*	X		X		X
White ibis	*Eudocimus albus*	X		X	X	X
Roseate spoonbill	*Ajaia ajaja*	X	X	X	X	X
Snow goose	*Chen caerulescens*	X				
Mottled duck	*Anas fulvigula*					X
Blue-winged teal	*Anas discors*	X	X	X		
Northern shoveler	*Anas clypeata*			X		
Canvasback	*Aythya valisineria*		X			
Red-breasted merganser	*Mergus serrator*		X			
White-tailed kite	*Elanus leucurus*	X	X			
Red-tailed hawk	*Buteo jamaicensis*	X				
Marsh hawk	*Circus cyaneus*	X	X		X	X

(Continued)

Table 4 (Continued)

Common Name	Scientific Name	Occurrence By Season Fall 76	Winter 76-7	Spring 77	Summer 77	Fall 77
Osprey	*Pandion haliaetus*	X	X			
American kestrel	*Falco sparverius*	X				X
Clapper rail	*Rallus longirostris*	X		X		X
American coot	*Fulica americana*	X				
American oystercatcher	*Haematopus palliatus*	X	X			
Semipalmated plover	*Charadrius semipalmatus*	X	X	X	X	X
Piping plover	*Charadrius melodus*	X	X	X		X
Wilson's plover	*Charadrius wilsonia*	X		X	X	X
Killdeer	*Charadrius vociferus*	X	X	X	X	X
Black-bellied plover	*Pluvialis squatarola*	X	X	X	X	X
Ruddy turnstone	*Arenarius interpres*	X	X	X	X	X
Long-billed curlew	*Numenius americanus*	X	X	X		X
Whimbrel	*Numenius phaeopus*			X		
Spotted sandpiper	*Actitis macularia*	X	X	X	X	X
Solitary sandpiper	*Tringa solitaria*			X		
Willet	*Catoptrophorus semipalmatus*	X	X	X	X	X
Greater yellowlegs	*Tringa melanoleucus*	X	X	X		X
Lesser yellowlegs	*Tringa flavipes*		X	X		
Red knot	*Calidris canutus*					
Pectoral sandpiper	*Calidris melanotos*			X		
White-rumped sandpiper	*Calidris fuscicollis*			X		
Least sandpiper	*Calidris minutilla*	X	X	X	X	X
Dunlin	*Calidris alpina*	X	X	X		X
Semipalmated sandpiper	*Calidris pusillus*			X	X	
Western sandpiper	*Calidris mauri*	X	X	X		X

(Continued)

Table 4 (Continued)

Common Name	Scientific Name	Occurrence By Season Fall 76	Winter 76-7	Spring 77	Summer 77	Fall 77
Sanderling	*Calidris alba*	X	X	X	X	X
Dowitcher	*Limnodromus sp.*	X	X	X	X	X
Marbled godwit	*Limosa fedoa*					X
American avocet	*Recurvirostra americana*	X	X			
Black-necked stilt	*Himantopus mexicanus*	X		X		X
Herring gull	*Larus argentatus*	X	X			X
Ring-billed gull	*Larus delawarensis*	X	X	X		X
Laughing gull	*Larus atricilla*	X	X	X	X	X
Gull-billed tern	*Gelochelidon nilotica*			X		
Forster's tern	*Sterna forsteri*		X	X	X	X
Least tern	*Sterna albifrons*	X		X	X	X
Royal tern	*Sterna maxima*	X	X		X	X
Caspian tern	*Sterna caspia*			X	X	X
Sandwich tern	*Sterna sandvicensis*	X			X	X
Black tern	*Chlidonias niger*	X			X	X
Black skimmer	*Rynchops niger*	X		X	X	X
Mourning dove	*Zenaida macroura*	X	X	X		X
Yellow-billed cuckoo	*Coccyzus americanus*	X		X		X
Short-eared owl	*Asio flammeus*		X			
Common nighthawk	*Chordeiles minor*	X		X	X	X
Chimney swift	*Chaetura pelagica*			X		
Ruby-throated hummingbird	*Archilochus colubris*			X		X
Belted kingfisher	*Megaceryle alcyon*	X				X
Common flicker	*Colaptes auratus*		X			X
Eastern kingbird	*Tyrannus tyrannus*	X		X	X	X

(Continued)

Table 4 (Continued)

Common Name	Scientific Name	Occurrence By Season				
		Fall 76	Winter 76-7	Spring 77	Summer 77	Fall 77
Scissor-tailed flycatcher	*Muscivora forficata*	X		X	X	X
Eastern phoebe	*Sayornis phoebe*			X		
Eastern wood pewee	*Contopus virens*	X				
Horned lark	*Eremophila alpestris*	X	X	X	X	X
Tree swallow	*Iridoprocne bicolor*			X		
Bank swallow	*Riparia riparia*			X		
Rough-winged swallow	*Stelgidopteryx ruficollis*	X		X		X
Barn swallow	*Hirundo rustica*	X		X	X	X
Purple martin	*Progne subis*			X	X	
Blue jay	*Cyanocitta cristata*	X				
House wren	*Troglodytes aedon*	X				X
Short-billed marsh wren	*Cistothorus platensis*					X
Mockingbird	*Mimus polyglottos*			X		X
Gray catbird	*Dumetella carolinensis*			X		
American robin	*Turdus migratorius*		X			
Hermit thrush	*Catharus guttatus*	X				
Swainson's thrush	*Catharus ustulatus*			X		
Veery	*Catharus fuscescens*			X		
Blue-gray gnatcatcher	*Polioptila caerulea*	X				X
Ruby-crowned kinglet	*Regulus calendula*	X	X			
Water pipit	*Anthus spinoletta*	X	X	X		
Loggerhead shrike	*Lanius ludovicianus*	X	X		X	X
White-eyed vireo	*Vireo griseus*			X		
Red-eyed vireo	*Vireo olivaceus*			X		
Black-and-white warbler	*Mniotilta varia*			X		

(Continued)

Table 4 (Continued)

Common Name	Scientific Name	Occurrence By Season Fall 76	Winter 76-7	Spring 77	Summer 77	Fall 77
Prothonotary warbler	*Protonotaria citrea*			X		
Worm-eating warbler	*Helmitheros vermivorus*			X		
Tennessee warbler	*Vermivora peregrina*			X		
Orange-crowned warbler	*Vermivora celata*			X		
Yellow warbler	*Dendroica petechia*			X		
Magnolia warbler	*Dendroica magnolia*			X		
Yellow-rumped warbler	*Dendroica coronata*	X	X	X		X
Black-throated green warbler	*Dendroica virens*			X		
Yellow-throated warbler	*Dendroica dominica*			X		
Blackpoll warbler	*Dendroica striata*			X		
Palm warbler	*Dendroica palmarum*					X
Ovenbird	*Seiurus aurocapillus*			X		
Northern waterthrush	*Seiurus noveboracensis*			X		
Common yellowthroat	*Geothlypis trichas*			X		
Yellow-breasted chat	*Icteria virens*			X		
Hooded warbler	*Wilsonia citrina*			X		X
American redstart	*Setophaga ruticilla*			X		
Eastern meadowlark	*Sturnella magna*	X	X			X
Red-winged blackbird	*Agelaius phoeniceus*	X	X	X	X	X
Orchard oriole	*Icterus spurius*	X				X
Northern oriole	*Icterus galbula*			X		X
Great-tailed grackle	*Quiscalus mexicanus*	X		X		X
Common grackle	*Quiscalus quiscula*	X			X	X
Brown-headed cowbird	*Molothrus ater*			X	X	
Cardinal	*Cardinalis cardinalis*			X		

(Continued)

Table 4 (Concluded)

Common Name	Scientific Name	Occurrence By Season Fall 76	Winter 76-7	Spring 77	Summer 77	Fall 77
Rose-breasted grosbeak	*Pheucticus ludovicianus*			X		
Blue grosbeak	*Guiraca caerulea*			X		
Indigo bunting	*Passerina cyanea*			X		
Painted bunting	*Passerina ciris*	X				
Ipswich sparrow	*Passerculus sandwichensis*	X	X	X		
LeConte's sparrow	*Ammospiza leconteii*					X
White-winged junco	*Junco hyemalis*	X	X			
Field sparrow	*Spizella pusilla*	X				
Swamp sparrow	*Melospiza georgiana*					X
Song sparrow	*Melospiza melodic*	X	X			X
	Total	75	47	91	37	69

Note: Taxonomy is according to American Ornithologists' Union (1957, 1973, and 1976).

Table 5

Mammal Species Noted in Bolivar Peninsula Baseline and Study Areas, with Their Abundance

Common Name	Scientific Name	Abundance in Baseline Area*	Abundance in Study Area*	Comments
Opossum	*Didelphis virginiana*	Common	Rare	Largely excluded from fenced area
Short-tailed shrew	*Blarina brevicauda*	Rare	Not observed	
Nine-banded armadillo	*Dasypus novemcinctus*	Very common	Rare	Largely excluded from fenced area
Eastern cottontail	*Sylvilagus floridanus*	Rare	Very common	Attracted to planted vegetation
Swamp rabbit	*Sylvilagus aquaticus*	Very common	Rare	
Marsh rice rat**	*Oryzomys palustris*	Not observed	Rare	Remained outside fence until vegetation developed
Hispid cotton rat**†	*Sigmodon hispidus*	Very common	Very common	Remained outside fence until vegetation developed
Norway rat**	*Rattus norvegicus*	Not observed	Rare	Introduced with humans and equipment
House mouse**†	*Mus musculus*	Common	Common	
Nutria	*Myocastor coypus*	Rare	Rare	
Raccoon	*Procyon lotor*	Very common	Common	
Eastern spotted skunk	*Spilogale putorius*	Rare	Not observed	
River otter	*Lutra canadensis*	Not observed	Rare	Attracted to fish and invertebrates around dike
Bobcat	*Felis rufus*	Rare	Not observed	
Cow	*Bos indicus*	Common	Common	Excluded from fenced area
Goat	*Capra hircus*	Very common	Very common	Excluded from fenced area
Sheep	*Ovis aries*	Common	Common	Excluded from fenced area

* Rare = seen one to two times.
Common = seen often.
Very common = seen on most or all visits.
** Trapped in study area.
† Trapped in baseline area.

Notes: 1. No federally designated endangered or threatened animal species were seen. The State of Texas protects one species observed, the nutria (*Myocaster coypus*).
2. Taxonomy is according to Jones et al. 1975.

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

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1. Bolivar Peninsula. 2. Dredged material disposal. 3. Environmental effects. 4. Field investigations. 5. Habitat development. 6. Habitats. 7. Marsh development. 8. Vegetation establishment. 9. Waste disposal sites. I. United States. Army. Corps of Engineers. II. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; D-78-15.

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Technical Report D-78-15

HABITAT DEVELOPMENT FIELD INVESTIGATIONS, BOLIVAR PENINSULA MARSH AND UPLAND HABITAT DEVELOPMENT SITE, GALVESTON BAY, TEXAS

APPENDIX A: BASELINE INVENTORY OF WATER QUALITY, SEDIMENT QUALITY, AND HYDRODYNAMICS

by

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P. O. Box 631, Vicksburg, Miss. 39180

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Final Report

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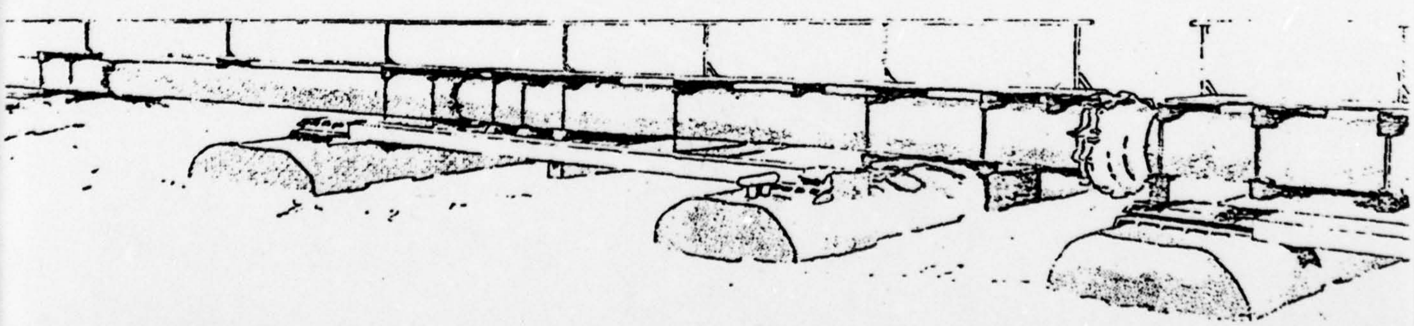

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HABITAT DEVELOPMENT FIELD INVESTIGATIONS, BOLIVAR PENINSULA
MARSH AND UPLAND HABITAT DEVELOPMENT SITE
GALVESTON BAY, TEXAS

Appendix A: Baseline Inventory of Water Quality, Sediment Quality, and Hydrodynamics

Appendix B: Baseline Inventory of Terrestrial Flora, Fauna, and Sediment Chemistry

Appendix C: Baseline Inventory of Aquatic Biota

Appendix D: Propagation of Vascular Plants and Postpropagation Monitoring of Botanical, Soil, Aquatic Biota, and Wildlife Resources

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Water and sediment quality and hydrodynamics in Galveston Bay at Bolivar Peninsula, Texas, were inventoried in connection with a proposed experimental marsh and upland habitat development project using dredged material.

Results of field studies at the site and a review of historical data considering various field parameters and nutrient, metal, insecticide, and herbicide concentrations in the water and sediments are presented; studies of tide and current conditions related to prevailing winds are described.

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20. ABSTRACT (Continued).

The water and sediments were found to be free of levels of metals or organic pollutants likely to adversely influence the experimental habitat development. Nutrient concentrations were low and dissolved oxygen values high. The site was influenced by small short-period waves that scour the sediments on the site. Water stages were between 0.85 and -0.37 m (National Geodetic Vertical Datum) 98 percent of the time and were strongly influenced by seasonal wind conditions. Winds from the northwest at 16 to 23 km/hr may lower the water stage as much as 0.30 m. Currents flowed in southwesterly and northeasterly directions with an average velocity of 21 cm/sec during usual tide and wind conditions.

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Summary

This report presents water quality, sediment quality, and hydrodynamic information collected by the U. S. Geological Survey during April, May, June, and August 1975, along with a review of selected historical data. The information was collected for use by the U. S. Army Corps of Engineers in evaluating environmental conditions at a proposed marsh and upland habitat development site on Bolivar Peninsula in Galveston Bay, Texas. The low concentrations of nitrogen and phosphorus species, the low biochemical oxygen demand (BOD), the low concentrations of heavy metals, the near absence of insecticide and herbicide residues, and the high dissolved oxygen saturation indicated that conditions at the test site were favorable for salt-marsh plant and animal growth.

Water velocities at the test site exceeded 30 cm/sec during one storm period but were less than 21 cm/sec during usual wind and tidal conditions. Water stages for 13 years of record were between 0.85 and -0.37 m (National Geodetic Vertical Datum) during 98 percent of the time. The mean water stage from October 1973 to September 1975 was 0.32 m.

The climate at the test site was described by data collected at the Galveston airport. The mean monthly air temperatures for 1940-60 were 12.3° to 28.8°C, and the mean annual temperature was 21.2°C. The mean monthly rainfall was 72.1 to 151.9 mm. The mean annual rainfall was 1160.8 mm.

Wind speeds greater than 21 km/hr, which occurred 45 percent of the days each year, caused changes in the water stages. West and northwest winds caused the greatest stage change for the least wind. Winds of 24 to 32 km/hr from any direction caused stage changes between 0.15 and 0.30 m, but southeast winds greater than 32 km/hr were required to cause more than an 0.30-m stage change.

Preface

Data presented in this report were collected under Interagency Agreement Nos. WESRF 75-95 and 76-59 dated 25 March 1975 and 18 November 1975, between the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, and the U. S. Geological Survey (USGS), Austin, Texas. The agreements were sponsored by the Office, Chief of Engineers, U. S. Army, under the Dredged Material Research Program (DMRP) which was managed by the Environmental Laboratory (EL), formerly the Environmental Effects Laboratory, WES.

Field collections and observations, sample analyses, and initial data reduction were conducted under the supervision of Mr. D. C. Hahl, Chief, Texas Bays and Estuaries Project, USGS, and transmitted to the Environmental Laboratory as an open-file report, "Data on Water Quality and Hydrodynamics at the Bolivar Wetland - Habitat Development Site, Galveston, Texas." Hydrologic aspects of the open-file report are contained herein as amplified and revised by Mr. Ellis J. Clairain, Jr., Fisheries Biologist, EL. Technical reviews and revisions of text and tabular materials for publication were made by Mr. John D. Lunz, Marine Biologist, EL, and Dr. John W. Simmers, Biologist, EL. The editorial supervisor was Ms. Dorothy P. Booth.

The agreement was monitored by Mr. Lunz and coordinated by Dr. John Byrne, Site Coordinator, EL.

The project was under the general supervision of Dr. H. K. Smith, Project Manager, Habitat Development Project; Dr. C. J. Kirby, Chief, Environmental Resources Division; and Dr. John Harrison, Chief, EL.

Commanders and Directors of WES during the preparation and publication of this report were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.

Contents

HABITAT DEVELOPMENT FIELD INVESTIGATIONS
BOLIVAR PENINSULA MARSH AND UPLAND
HABITAT DEVELOPMENT SITE
GALVESTON BAY, TEXAS

APPENDIX A: BASELINE INVENTORY OF WATER QUALITY, SEDIMENT QUALITY, AND HYDRODYNAMICS

Introduction

1. This report presents water quality, sediment quality, water stage, and water velocity and direction data collected by the U. S. Geological Survey (USGS) in response to a 30 January 1975 request from the U. S. Army Engineer Waterways Experiment Station (WES) to participate in a study of environmental conditions at the Bolivar Peninsula habitat development site (Figure 1).

2. The Bolivar Peninsula test site is located near lat. 29°25'N and long. 94°44'W about 20.1 km northeast of the Galveston, Texas, airport. The test site is in the Galveston Bay reach of the Trinity-San Jacinto Estuary about 6.4 km from the western end of Bolivar Peninsula.

3. The objective of the program is to develop a marsh and upland habitat complex using dredged material from the Intracoastal Waterway as a substrate. The dredged material will be protected by a dike. The objective of the work by the USGS was to document the water and sediment quality and hydrodynamic conditions at the proposed project location.

4. To achieve the objectives, the USGS scheduled hydrologic studies prior to and during development of the site. In the conduct of these studies, the USGS arranged:

- a. To review and summarize climatic data for the nearest weather station.
- b. To collect water quality and sediment quality data at the test site and to perform a literature search to ascertain the applicability of historical data.
- c. To establish a water stage recorder at the test site or determine historical water stages by correlation of

the test site data with data from a nearby long-term water stage recorder and evaluate changes in water stage due to wind velocities.

d. To measure water velocities and directions at the test site during extreme conditions.

5. The work proposal and sampling sites (Figure 2) were agreed upon by USGS and WES representatives, and work began in April 1975. By June 1975, a water stage recorder was installed; three water quality surveys were completed; water velocities were measured; and historical water quality, climatological, and water stage data were obtained. In September 1975, a change in dredging plans by the Corps of Engineers caused discontinuance of all work by the USGS except operation of the water stage recorder.

Climate

6. The test site is on the bayward side of a 3.2-km-wide barrier peninsula along the Gulf of Mexico. The following data, taken from "Climatography of the United States" (U. S. Weather Bureau 1965), indicate the mild climate of the area.

7. Mean monthly air temperatures at the Galveston airport for 21 years of record (1940-60) ranged from a high of 28.8°C to a low of 12.3°C. The mean annual temperature was 21.2°C. Air temperature for 10 years of record (1951-60) was 32.2°C or more on an average of 35 times a year and was 0°C or less on an average of only 2 times a year. The extreme temperatures recorded in Galveston during 1951-60 were 36.7° and -7.8°C.

8. Mean monthly rainfall at Galveston airport for 21 years of record (1940-60) ranged from a high of 151.9 mm to a low of 72.1 mm. The mean annual rainfall was 1160.8 mm. Rainfall for 10 years of record (1951-60) was 12.7 mm or more on an average of 23 days a year and for 7 years of record (1954-60) was 2.5 mm or less on an average of 52 days a year.

9. Frequency of wind occurrence and mean wind velocity data based on 87,690 hourly observations during the 10-year period 1951-60 (U. S. Weather Bureau 1962) for the Galveston airport are summarized in Table 1. These data show that winds occur on an average of 99 percent of the days each year and that the mean daily wind speed exceeds 21 km/hr 45 percent of the days each year.

10. The selection of the two periods shown in Table 1 is based on predominant wind directions. From March through August, wind is from the south quadrant 69 percent of the days; from September through February, wind is from the northeast quadrant 46 percent of the days.

Water and Sediment Quality

11. Water and sediment quality at the proposed site were determined by considering both historical data from the area and an analysis of water and sediment samples collected by the USGS during this project.

Historical data

12. As part of its Galveston Bay project, the Texas Water Quality Board (TWQB) conducted an extensive sampling program in the bay from July 1968 to September 1971. Samples were collected monthly from 15 to 39 stations, at 2- or 3-hour intervals during five 24-hour periods. The data collected during this period and related material are presented in a publication by Huston (1971). The TWQB site 29, located at the Hanna Reef tide gage shown in Figure 1, was sampled 27 times during the TWQB study. Review of the data from site 29 and TWQB data from other sites in Galveston Bay indicates that water quality was nearly uniform in the area of the bay between Bolivar Peninsula and Hanna Reef; therefore, data from site 29 can be considered representative of conditions at the test site from July 1968 to September 1971.

Data collection and analysis during this project

13. During April, May, June, and August 1975, in situ measurements of dissolved oxygen (DO), pH, specific conductance, and temperature were made, and laboratory analyses for nutrients, major constituents, metals,

insecticides, herbicides, and radiochemicals were performed. Specific parameters and procedures for both field collection/analysis and laboratory analysis are presented in Table 2.

14. Table 3 is a comparison of water quality data for samples collected at a depth of 0.3 m from July 1968 to September 1971 by the TWQB at site 29 and of similar data for samples collected at depths of 0.3 up to 4.9 m from April to August 1975 by the USGS at the Bolivar Peninsula test site. All of the water and sediment data collected for this project by the USGS are presented in Tables 4-10.

15. Data collected by the USGS show that the differences in chemical and physical characteristics between water in the bay and water in the Intracoastal Waterway are minor except for the dissolved oxygen concentration, which averaged about 0.5 mg/ℓ less in the Intracoastal Waterway.

16. Turbidity at the test site is a direct function of wave energy. On 14 May 1975, after 2000 hours, northerly winds increased to about 32 km/hr. The turbidity increased through the night until a predawn lessening of the wind reduced the wave heights. Through 16 May 1975, winds continued at speeds greater than 24 km/hr and the turbidity remained high. Southerly winds during the April, June, and August 1975 sampling periods were less than 24 km/hr, and the resultant turbidities were much less than in May.

17. The concentrations of nitrogen species were low, but phosphorus concentrations ranged from 0.06 to 0.35 mg/ℓ. Biochemical oxygen demand (BOD) did not exceed 2.7 mg/ℓ, indicating that a deficiency of dissolved oxygen would not occur.

18. Analyses for minor elements and pesticides showed that the concentrations of these constituents were low; most of them were too low for the analytical methods to detect. Results of an analysis for lead, mercury, and zinc based on samples collected in 1972 about 91 m from line 610, site 40 (Galveston District 1975), showed concentrations

of the same order of magnitude as those collected by the USGS in 1975 (USGS 1976).

19. The low concentrations of nitrogen and phosphorus species, the low BOD, the low concentrations of heavy metals, the absence of insecticide and herbicide residues, and the high dissolved oxygen saturation indicate that the Bolivar Peninsula test site is nearly free of pollutants; therefore, marsh development at the site should not be adversely affected by water quality.

Water Velocities and Directions

20. Water velocities and directions were measured hourly at line 640, site 40, from 1425 hours on 14 May until 0100 hours on 16 May 1975. Surface winds during this sampling period were from the north at 24 to 32 km/hr. Measurements were repeated at this site during the period from 1300 hours on 25 June until 1200 hours on 26 June 1975. During the June sampling period, winds were from the southeast and moderate. Observations were also made on line 620, site 40, during the same periods in May and June. However, these measurements were obtained only when the water depth allowed boat access to the site. The data for both sampling periods are presented in Tables 11 and 12.

21. Water velocities and directions at line 640, site 40, differed significantly between May and June (Figure 3). In May, with the strong northerly wind predominant, water movement was to the southwest 80 percent of the time, and water velocity averaged 24.4 cm/sec. Northeasterly water movement only occurred 20 percent of the time, and water velocity averaged 21.0 cm/sec.

22. During the June sampling period, when moderate winds were from the southeast, flow at line 640, site 40, was to the southwest 38 percent of the time, and velocity averaged only about half (13.6 cm/sec) of that observed in May. Flow to the northeast, however, occurred 62 percent of the time with an average velocity of 12.5 cm/sec.

23. At line 620, site 40, close to the proposed habitat development project dike, only 7 observations were made in May and 19 in June 1975. May current measurements, made during the strong northerly wind, are presented in Figure 4. The average current velocity during the sampling period was 14.8 cm/sec, and all flow was in a southwesterly direction.

24. In June, with the moderate southeasterly winds, current velocity averaged 7.7 cm/sec for the 39 percent of the time that flow was to the southwest. During the remaining 61 percent of the time, average current velocity was 10.0 cm/sec, and flow was to the northeast (Figure 4).

25. In summary, observations made during this study show that currents flow parallel to the proposed site in Galveston Bay regardless of the tide or wind condition. Water velocities and directions are influenced by both wind and tide. Effects of northeast winds blowing water out of the bay are negated by incoming tides during short periods of large stage differences between the gulf and the bay. Velocity difference during a tide cycle or between different tide cycles is a function of head differences if wind can be ignored. Antecedent wind and water stages have a marked effect on velocities. Nearshore current speeds were lower than offshore current speeds during both sampling periods.

Water Stages

26. A water stage recorder was installed at the test site on 16 May 1975. Datum of the gage was set to that of the U. S. Army Corps of Engineers benchmark (BM) 2960 + 43.9 at 1.786 m National Geodetic Vertical Datum (NGVD) as determined in 1975. By using a water level datum transfer based on 39 days of nonstorm record, it was determined that the datum of the gage at Hanna Reef must be raised by 0.378 m to agree with the NGVD elevation for BM 2960 + 43.9.

The following discussion of water stages is based on the datum of BM 2960 + 43.9.

27. The range in water stage for the period January 1963 through September 1975 at Hanna Reef was 1.28 to -1.07 m. However, during about 98 percent of that period, water stages were between 0.85 and -0.37 m; during more than 50 percent of the period, water stages were between 0.70 and -0.21 m.

28. A few storms occurred during the period of common record between the gages at Hanna Reef and the test site. This common record indicates that water stages are the same at both places when water is being blown into the bay, but that water stages are different when water is being blown out of the bay. Tides driven by northerly winds overrun the land, and during moderate storms, the overrun persists for most of the storm period and appears to cause stages as much as 0.06 m higher at the test site than those at Hanna Reef.

29. The wake from oceangoing vessels causes significant wave action at the site. These waves are 0.3 m or more in height; they occur in groups; and they roll onto the shore with surflike action. These groups of waves, even though they occur at irregular intervals, probably will have an undetermined effect on the test site.

30. Review of the data suggests that historical records for the gage at Hanna Reef represent water stages at the test site most of the time. The mean water stage at Hanna Reef, adjusted to the datum of BM 2960 + 43.9, for the 24 months from October 1973 through September 1975 is 0.317 m. An illustration of application of the historical water stage data to the elevation specifications of the proposed habitat development project is presented by Figure 5.

Deviations of Water Stages

31. Deviations in water stage from symmetrical tidal fluctuations are usually caused by wind. Daily wind data for 1974 (National Oceanic and Atmospheric Administration 1974) were obtained from the

AD-A063 780 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS F/G 13/3
HABITAT DEVELOPMENT FIELD INVESTIGATIONS, BOLIVAR PENINSULA MAR--ETC(U)
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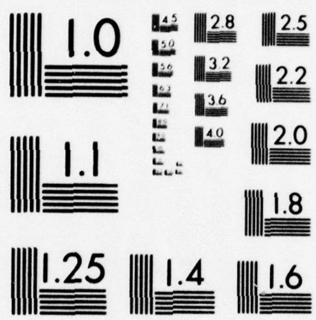

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Galveston office of the National Weather Service, tabulated, and reduced, and tide charts for Galveston Bay at the Hanna Reef tide gage were obtained from the Galveston District. For periods of wind greater than 23 km/hr during 1974, the daily mean wind velocities and directions were selected from the National Weather Service data; corresponding deviations in tide stage as recorded on the tide charts were noted. These paired events were grouped first by wind direction and second by wind velocity. The data were then sorted by the magnitude of the change in stage. The results are given in Table 13.

32. The greatest deviations from mean water stage occur with winds from the west and northwest. It appears that westerly winds may either decrease the water stage when combined with an ebbing tide or increase the water stage by action with the flooding tide. Northwesterly winds tend to push water out of the bay or retard water entering the bay. Winds off the Gulf of Mexico from the south, southeast, and southwest all tend to increase the mean water stage by moving water into or holding water in the bay. For the period of record in 1974, wind conditions from the southeast were most common, and velocities often exceeded 32 km/hr raising water stages by 0.3 m. Less common winds from the southwest had similar effects at more moderate velocities of 24 to 32 km/hr.

33. Different antecedent wind velocities and the coincidence of peak winds with high or low tides alter the magnitude of the recorded changes in stage. Although antecedent conditions were not examined, the data in Table 13 show that different wind velocities have unique effects on water stages. The magnitude and frequency of deviation from usual tidal stages and the time of year that the deviations should occur can be inferred by a combination of the information contained in Tables 1 and 13.

34. Winter wind conditions favor a lower mean water stage than spring and summer conditions. September to February wind conditions during the 10-year period of record (1951-60) were characterized by dominant winds (condition based on percent frequency of occurrence)

varying between those that tend to increase water stages and those that decrease water stages. Strongest average wind velocities occur in winter from the north, northeast, and northwest, conditions that favor greatest downward deviations in water stage. By comparison with winter wind conditions, spring and summer winds predominantly come from southerly directions and tend to increase the mean water stage.

Conclusions and Recommendations

35. Water quality and sediment quality parameters are favorable for the establishment and growth of salt-marsh plants and animals. Phosphorus and nitrogen species were present in low concentrations as were heavy metals. Additionally, herbicide and insecticide residues were absent, BOD was low, and dissolved oxygen saturation was high.

36. Current velocities exceeded 30 cm/sec only during one storm period and were less than 21 cm/sec during usual wind and tide conditions. Water stages for 98 percent of the period January 1963-September 1975 were 0.85 to -0.37 m, and the mean water stage for the period October 1973-September 1975 was 0.317 m.

37. The historical climate information for 1940-60 indicated mean monthly temperatures of 12.3^{o} to 28.8^{o}C and a mean annual temperature of 21.2^{o}C. The mean monthly rainfall was 72.1 to 151.9 mm, and the mean annual rainfall was 1160.8 mm.

38. Wind velocities greater than 21 km/hr occurred 45 percent of the days each year and caused changes in the water stage. West and northwesterly winds caused the greatest stage change for the least wind. Winds of 24 to 32 km/hr from any direction caused stage changes of 0.15 to 0.30 m, but southeasterly winds had to be greater than 32 km/hr to cause more than a 0.30-m stage change.

39. The test site is an environment characterized by high wave energy. Development of a gulf coast salt marsh would be facilitated by the absence of water and sediment pollutants but would require protection from the wave actions and water stage fluctuations, as well as selection of species adaptable to this energy regime.

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Table 1

Frequency and Mean Velocity of Surface Winds, Galveston Airport, 1951-1960*

Wind Direction	September-February: Mean Daily Wind Speed km/hr	September-February: Percent of Days with Wind	September-February: Percent of Days with Wind 20.9-38.6 km/hr	September-February: Percent of Days with Wind >38.6 km/hr	March-August: Mean Daily Wind Speed km/hr	March-August: Percent of Days with Wind	March-August: Percent of Days with Wind 20.9-38.6 km/hr	March-August: Percent of Days with Wind >38.6 km/hr
North	24.5	15.6	8.2	1.5	20.9	6.4	3.0	0.6
Northeast	22.0	15.0	7.0	0.8	19.5	6.4	2.7	0.1
East	20.1	15.2	6.3	0.4	19.3	9.5	4.5	0.0
Southeast	18.0	21.1	6.8	0.1	19.5	26.0	12.0	0.2
South	18.5	15.2	5.3	0.1	20.3	32.2	15.3	0.1
Southwest	18.3	5.6	2.0	0.2	18.2	10.7	4.5	0.1
West	16.7	3.9	1.1	0.1	17.1	3.6	0.8	0.1
Northwest	22.0	7.2	3.4	0.7	20.1	4.3	1.5	0.4
--	Calm	1.2	--	--	Calm	0.9	--	--
Total	--	100.0	40.1	3.9	--	100.0	44.3	1.6
Average	20.0	--	--	--	19.4	--	--	--

* Adapted from U. S. Geological Survey open-file report.

Table 2

Water and Sediment Quality Parameters and Procedures

Parameter	Sample Type	Collection/In Situ Analysis	Method of Analysis	Reference	Table
SiO_2	Water	Drawn from submerged in situ analysis probe holding manifold	Atomic absorption	Brown et al. (1974)	5
NO_3	Water (total)	"	Brucine (spectrophotometric, manual)	"	5
NH_3	Water (total)	"	Diazotization (spectrophotometric, manual)	"	5
NO_2	Water (total)	"	Distillation (spectrophotometric, manual)	"	5
Total P	Water (total)	"	Phosphomolybdate (spectrophotometric, manual)	"	5
BOD	Water (total)	"	Manometric	"	5
Ca	Water	"	Atomic absorption	"	6
Mg	Water	"	Atomic absorption	"	6
Na	Water	"	Atomic absorption	"	6
K	Water	"	Atomic absorption	"	6
HCO_3	Water	"	Manual calculation	"	6
SO_4	Water	"	Thorin (spectrophotometric, manual)	"	6

(Continued)

(Sheet 1 of 6)

Table 2 (Continued)

Parameter	Sample Type	Collection/In Situ Analysis	Method of Analysis	Reference	Table
Cl (Chloride)	Water	Drawn from submerged in situ analysis probe holding manifold	Mohr (Titrimetric, manual)	Brown et al. (1974)	6
Total dissolved solids	Water	"	Manual calculation	"	6
Al (aluminum)	Water	"	Ferron-orthophen-anthroline (spectro-photometric, manual)	"	7
As	Water	"	Silver-diethyldithi-ocarbamate (spectro-photometric, manual)	"	7
	Sediment	Ponar grab	Silver-diethyldithi-ocarbamate (spectro-photometric, manual)	"	7
Cd	Water	Drawn from manifold	Atomic absorption	"	7
	Sediment	Ponar grab	Atomic absorption	"	7
Cr	Water	Drawn from manifold	Atomic absorption	"	7
Co	Water	Drawn from manifold	Atomic absorption	"	7
	Sediment	Ponar grab	Atomic absorption	"	7
Cu	Water	Drawn from manifold	Atomic absorption	"	7
	Sediment	Ponar grab	Atomic absorption	"	7

(Continued)

Table 2 (Continued)

Parameter	Sample Type	Collection/In Situ Analysis	Method of Analysis	Reference	Table
CN	Sediment	Ponar grab	Pyridine-pyrazolone (spectrophotometric, manual)	Brown et al. (1974)	7
Fe	Water	Drawn from manifold	Atomic absorption	"	7
Pb	Water	Drawn from manifold	Atomic absorption	"	7
	Sediment	Ponar grab	Atomic absorption	"	7
Li	Water	Drawn from manifold	Atomic absorption	"	7
Mn	Water	Drawn from manifold	Atomic absorption	"	7
	Sediment	Ponar grab	Atomic absorption	"	7
Hg	Water	Drawn from manifold	Atomic absorption	USGS (1976)	7
	Sediment	Ponar grab	Atomic absorption	USGS (1976)	7
Ni	Water	Drawn from manifold	Atomic absorption	Brown et al. (1974)	7
Sr	Water	Drawn from manifold	Atomic absorption	"	7
Zn	Water	Drawn from manifold	Atomic absorption	"	7
	Sediment	Ponar grab	Atomic absorption	"	7
Aldrin	Water (total)	Drawn from manifold	Gas chromatography	Goerlitz and Brown (1972)	8
	Sediment	Ponar grab	Gas chromatography	"	8
Chlordane	Water (total)	Drawn from manifold	Gas chromatography	"	8
	Sediment	Ponar grab	Gas chromatography	"	8

(Continued)

Table 2 (Continued)

Parameter	Sample Type	Collection/In Situ Analysis	Method of Analysis	Reference	Table
DDD	Water (total)	Drawn from manifold	Gas chromatography	Goerlitz and Brown (1972)	8
	Sediment	Ponar grab	"	"	8
DDE	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8
DDT	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8
Dieldrin	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8
Endrin	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8
Heptachlor	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8
Heptachlor-epoxide	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8
Lindane	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8
Parathion	Water (total)	Drawn from manifold	"	"	8
Methyl parathion	Water (total)	Drawn from manifold	"	"	8

(Continued)

Table 2 (Continued)

Parameter	Sample Type	Collection/In Situ Analysis	Method of Analysis	Reference	Table
Malathion	Water (total)	Drawn from manifold	Gas chromatography	Goerlitz and Brown (1972)	8
Diazinon	Water (total)	Drawn from manifold	"	"	8
PCB	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8
2,4-D	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8
2,4,5-T	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8
Silvex	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8
Toxaphene	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8
Ethion	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8
Methyl-trithion	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8
Trithion	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8

(Continued)

Table 2 (Concluded)

Parameter	Sample Type	Collection/In Situ Analysis	Method of Analysis	Reference	Table
Organic Carbon	Water	Drawn from manifold	Infrared analysis	Goerlitz and Brown (1972)	9
	Suspended	Drawn from manifold	"	"	9
	Total	Drawn from manifold	"	"	9
RA-226	Water	Drawn from manifold	"	"	10
U	Water	Drawn from manifold	"	"	10
Gross α (U-NAT)	Water	Drawn from manifold	"	"	10
	Suspended	Drawn from manifold	"	"	10
Gross β (SR 90/Y 90)	Water	Drawn from manifold	"	"	10
	Suspended	Drawn from manifold	"	"	10
Gross β (CS-137)	Water	Drawn from manifold	"	"	10
	Suspended	Drawn from manifold	"	"	10
Filterable residue	Water (total)	Drawn from manifold	"	"	10
Nonfilterable residue	Water (total	Drawn from manifold	"	"	10

(Sheet 6 of 6)

Table 3

Comparison of Water Quality Data Collected Near Hanna Reef With That Collected Near Bolivar Peninsula Test Site

Parameter	Hanna Reef Site 29 Data*	Bolivar Peninsula Test Site Data**	Mean Value at Surface+ For All Sampling Sites
Organic nitrogen, mg/ℓ			--
Maximum	1.3	--	
Minimum	0.4	--	
Mean ($\bar{x}$)	0.7	--	
Total nitrate, mg/ℓ			0
Maximum	0.2	0.0	
Minimum	<0.05	0.0	0
Mean ($\bar{x}$)	0.1	--	0
Ammonia nitrogen, mg/ℓ			
Maximum	1.3	0.13	
Minimum	0.0	0.00	0.01
Mean ($\bar{x}$)	0.06	--	0.02
Total nitrite, mg/ℓ			
Maximum	0.05	0.01	
Minimum	<0.005	0.00	0.005
Mean ($\bar{x}$)	0.01	--	0.003
Total phosphorus, mg/ℓ			
Maximum	0.63	0.35	
Minimum	0.06	0.06	0.18
Mean ($\bar{x}$)	0.28	--	0.19

(Continued)

Table 3 (Continued)

Parameter	Hanna Reef Site 29 Data*	Bolivar Peninsula Test Site Data**	Mean Value at Surface+ For All Sampling Sites
Dissolved organic carbon, mg/ℓ			
Maximum	--	15	
Minimum	--	5.0	6.5
Mean ($\bar{x}$)	--	--	7.5
Suspended organic carbon, mg/ℓ			
Maximum	--	1.4	
Minimum	--	0.6	0.9
Mean ($\bar{x}$)	--	--	1.0
Dissolved oxygen, mg/ℓ			
Maximum	11.1	10.1	
Minimum	5.4	5.6	8.6
Mean ($\bar{x}$)	8.0	--	8.2
BOD, mg/ℓ			
Maximum	4	2.7	
Minimum	0	0.5	1.4
Mean ($\bar{x}$)	2	--	1.7
Total coliform, MPN/100 ml			
Maximum	200	--	
Minimum	<2	--	
Mean ($\bar{x}$)	15	--	
Fecal coliform, MPN/100 ml			
Maximum	23	--	
Minimum	<2	--	
Mean ($\bar{x}$)	<2	--	

(Continued)

Table 3 (Concluded)

Parameter	Hanna Reef Site 29 Data*	Bolivar Peninsula Test Site Data**	Mean Value at Surface+ For All Sampling Sites
Specific conductance, μmhos			
Maximum	37,600	30,000	
Minimum	7,400	11,000	14,655.2
Mean ($\bar{x}$)	22,300	--	14,755.6
Turbidity, JTU			
Maximum	--	275	
Minimum	--	5	69.1
Mean ($\bar{x}$)	--	--	97.9
Temperature, °C			
Maximum	30.2	29.0	
Minimum	7.6	23.3	26.4
Mean ($\bar{x}$)	20.3	--	26.1

(Sheet 3 of 3)

Note: It should be remembered that the Hanna Reef Site 29 data were collected monthly over a period exceeding 3 years (Huston 1971), and that the Bolivar Peninsula test site data were collected by the USGS during 4 months of a single year (1975).

*Based on samples collected from a depth of 0.3 m.

**Based on samples collected from a depth of 0.3 m and other depths up to 4.9 m.

+Surface samples are those collected from a depth of 0.3 m.

Table 4

Bolivar Peninsula Test Site Data; Field Determinations*

Date of Collection	Time	Site	Depth (m)	Specific Conductance (μmhos) (Field)	Temperature (°C)	pH	Dissolved Oxygen (mg/ℓ)	Percent Saturation	Turbidity (JTU)	Transparency Secchi Disk (cm)
				Line 610						
Apr 25, 75	1500	40	0.3	18000	24.7	8.2	8.8	111	10	--
			1.5	18000	24.6	8.2	8.7	110	5	--
			3.0	19000	23.9	8.2	8.2	102	10	--
			4.9	19000	23.9	8.1	8.1	101	10	--
Jun 24, 75	1245	40	0.3	16000	27.2	8.3	7.9	103	25	62
			1.5	16000	27.2	8.2	7.5	97	25	--
			3.0	18000	27.2	8.2	6.9	91	25	--
			4.9	18000	27.2	8.2	7.0	92	60	--
Aug 06, 75	1040	40	0.3	23000	28.8	--	7.2	100	10	81
			1.5	23000	28.0	--	5.6	77	20	--
			3.0	30000	28.2	--	6.0	86	15	--
			4.6	30000	28.0	--	5.9	84	15	--
				Line 620						
Apr 25, 75	1430	40	0.3	19000	26.7	8.4	9.3	122	15	--
			0.6	19000	26.6	8.4	9.3	122	30	--
Jun 24, 75	1400	40	0.3	17000	26.6	8.3	9.2	121	50	45
			0.6	17000	26.6	8.3	8.8	116	50	--

(Continued)

* Taken from U. S. Geological Survey open-file report.

(Sheet 1 of 5)

Table 4 (Continued)

Date of Collection	Time	Site	Depth (m)	Specific Conductance (μmhos) (Field)	Temperature (°C)	pH	Dissolved Oxygen (mg/ℓ)	Percent Saturation	Turbidity (JTU)	Transparency Secchi Disk (cm)
					Line 620 Continued					
Aug 06, 75	1245	40	0.5	17000	29.0	--	8.7	119	--	--
					Line 630					
Apr 25, 75	1415	40	0.3	19000	25.3	8.4	9.5	122	10	--
			1.1	19000	25.2	8.4	9.5	120	10	--
Jun 24, 75	1345	40	0.3	16000	26.9	8.3	8.7	114	25	55
			1.2	17000	26.7	8.3	8.1	107	40	--
Aug 06, 75	1230	40	0.3	18000	28.5	--	8.0	108	15	--
			1.1	25000	28.0	--	7.0	97	20	--
					Line 640					
Apr 25, 75	1330	40	0.3	18000	24.9	8.4	9.3	118	10	--
			0.9	18000	24.7	8.4	9.3	118	10	--
			1.4	18000	24.6	8.4	9.1	115	10	--
May 14, 75	1425	40	0.3	13000	27.7	--	9.1	118	55	--
			1.2	13000	27.0	--	9.3	119	70	--
May 14, 75	1500	40	0.3	14000	27.9	--	9.1	120	40	--
			1.2	14000	26.8	--	8.8	113	85	--
May 14, 75	1600	40	0.3	13000	28.2	--	9.6	126	35	--
			1.4	15000	26.5	--	8.9	114	80	--

(Continued)

Table 4 (Continued)

Date of Collection	Time	Site	Depth (m)	Specific Conductance (μmhos) (Field)	Temperature (°C)	pH	Dissolved Oxygen (mg/ℓ)	Percent Saturation	Turbidity (JTU)	Transparency Secchi Disk (cm)
				Line 640 Continued						
May 14, 75	1700	40	0.3	13000	28.3	--	10.1	133	30	--
			1.4	15000	26.6	--	7.2	94	60	--
May 14, 75	1805	40	0.3	14000	27.8	--	10.0	132	30	--
			1.4	15000	26.5	--	7.4	95	50	--
May 14, 75	1900	40	0.3	14000	27.6	--	9.8	127	30	--
			1.4	17000	26.4	--	7.2	94	60	--
May 14, 75	2000	40	0.3	14000	27.3	--	9.3	121	30	--
			1.4	15000	26.5	--	7.6	97	50	--
May 14, 75	2230	40	0.6	12000	26.8	8.2	8.9	114	--	--
			1.4	12000	26.8	8.1	8.7	112	120	--
May 14, 75	2400	40	0.6	12000	26.3	8.3	8.3	105	--	--
			1.2	12000	26.3	8.2	8.2	104	170	--
May 15, 75	0105	40	1.1	11000	25.5	8.1	8.2	101	190	--
May 15, 75	0205	40	1.1	12000	25.0	8.3	7.9	98	230	--
May 15, 75	0305	40	1.1	12000	24.7	8.2	7.9	98	180	--
May 15, 75	0410	40	1.0	12000	24.4	8.2	7.9	96	170	--
May 15, 75	0505	40	1.0	12000	24.0	7.9	7.9	96	180	--
May 15, 75	0610	40	1.1	12000	23.8	8.2	7.9	96	170	--
May 15, 75	0710	40	1.2	11000	23.4	8.2	7.8	93	180	--

(Continued)

Table 4 (Continued)

Date of Collection	Time	Site	Depth (m)	Specific Conductance (µmhos) (Field)	Temperature (°C)	pH	Dissolved Oxygen (mg/ℓ)	Percent Saturation	Turbidity (JTU)	Transparency Secchi Disk (cm)
Line 640 Continued										
May 15, 75	0810	40	1.1	11000	23.7	8.3	7.6	90	130	--
May 15, 75	0930	40	0.3	12000	24.3	8.4	7.7	94	140	--
			1.2	12000	23.9	8.0	7.9	96	240	--
May 15, 75	1000	40	0.3	12000	24.5	8.4	7.6	93	130	--
			1.2	12000	24.4	8.2	7.7	94	260	--
May 15, 75	1100	40	0.3	12000	24.4	--	7.8	95	120	--
			1.2	12000	24.5	--	7.9	96	200	--
May 15, 75	1200	40	0.3	12000	24.8	--	7.9	98	105	--
			1.2	12000	24.9	--	8.0	99	200	--
May 15, 75	1300	40	0.3	12000	25.2	--	8.1	100	80	--
			1.2	12000	25.4	--	8.2	102	100	--
May 15, 75	1400	40	0.3	12000	25.4	--	8.5	106	100	--
			1.2	12000	25.7	--	8.5	106	95	--
May 15, 75	1500	40	0.3	12000	25.1	--	8.4	104	115	--
			1.4	12000	25.1	--	8.6	106	150	--
May 15, 75	1600	40	0.3	12000	25.3	--	8.4	105	150	--
			1.2	12000	25.2	--	8.8	109	225	--
May 15, 75	1700	40	0.3	11000	25.7	--	8.0	99	210	--
			1.2	11000	25.7	--	8.3	102	275	--

(Continued)

Table 4 (Concluded)

Date of Collection	Time	Site	Depth (m)	Specific Conductance (μmhos) (Field)	Temperature (°C)	pH	Dissolved Oxygen (mg/ℓ)	Percent Saturation	Turbidity (JTU)	Transparency Secchi Disk (cm)
				Line 640 Continued						
May 15, 75	1800	40	0.3	11000	25.4	--	8.2	101	190	--
			1.2	11000	25.5	--	8.3	102	270	--
May 15, 75	1900	40	0.3	11000	25.2	--	8.1	99	200	--
			1.2	11000	25.3	--	8.5	105	200	--
May 15, 75	2010	40	0.6	11000	24.9	--	8.1	99	--	--
			1.3	11000	24.8	--	8.2	100	200	--
May 15, 75	2110	40	0.6	11000	24.6	--	8.0	98	--	--
			1.3	11000	24.5	--	8.1	98	240	--
May 15, 75	2210	40	0.6	11000	24.4	--	7.9	96	--	--
			1.2	12000	24.2	--	7.9	96	180	--
May 15, 75	2300	40	0.6	12000	24.0	--	7.9	96	--	--
			1.2	12000	23.8	--	7.9	96	200	--
May 15, 75	2400	40	0.6	13000	23.6	--	7.9	95	--	--
			1.1	13000	23.5	--	7.9	95	150	--
May 16, 75	0100	40	0.6	12000	23.4	--	7.8	94	--	--
			1.1	12000	23.3	--	7.9	95	130	--
Jun 24, 75	1320	40	0.3	16000	26.9	8.3	8.5	112	25	53
			1.4	19000	27.3	8.2	6.8	91	60	--
Aug 06, 75	1215	40	0.3	21000	28.4	--	7.4	101	20	--
			1.2	28000	28.4	--	6.3	89	20	--

(Sheet 5 of 5)

Table 5

Bolivar Peninsula Test Site Data; Nutrients and Other Environmental Characteristics*

Date of Collection	Time	Site	Depth (m)	Dissolved Silica (SiO_2) (mg/ℓ)	Total Nitrate (N) (mg/ℓ)	Ammonia Nitrogen (N) (mg/ℓ)	Total Nitrite (N) (mg/ℓ)	Dissolved Phosphorus Ortho (P) (mg/ℓ)	Total Phosphorus (P) (mg/ℓ)	Biochemical Oxygen Demand (BOD) (mg/ℓ)	Chemical Oxygen Demand (COD) (mg/ℓ)
						Line 610					
Apr 25, 75	1500	40	0.3	2.2	0.0	0.00	0.00	--	0.06	2.3	--
			4.9	2.1	0.0	0.02	0.00	--	0.08	2.3	--
Jun 24, 75	1245	40	0.3	2.5	0.0	0.04	0.00	--	0.19	1.2	--
			4.9	2.4	0.0	0.07	0.01	--	0.19	1.0	--
Aug 06, 75	1040	40	0.3	--	0.0	0.01	0.01	--	0.27	--	--
			4.6	4.4	0.0	0.01	0.01	--	0.27	1.4	--
						Line 620					
Apr 25, 75	1430	40	0.6	1.9	0.0	0.01	0.00	--	0.08	2.5	--
Jun 24, 75	1400	40	0.3	2.5	0.0	0.01	0.01	--	0.18	1.1	--
Aug 06, 75	1245	40	0.5	6.4	0.0	0.01	0.00	--	0.28	2.1	--
						Line 630					
Apr 25, 75	1415	40	1.1	2.2	0.0	0.00	0.00	--	0.07	2.1	--
Jun 24, 75	1345	40	0.3	2.5	0.0	0.01	0.01	--	0.17	0.6	--
Aug 06, 75	1230	40	1.1	--	0.0	0.03	0.00	--	0.35	--	--
						Line 640					
Apr 25, 75	1330	40	0.3	2.1	0.0	0.01	0.00	--	0.09	2.4	--
			1.4	2.1	0.0	0.01	0.00	--	0.10	2.3	--
Jun 24, 75	1320	40	0.3	2.6	0.0	0.01	0.01	--	0.17	0.9	--
			1.4	2.5	0.0	0.13	0.00	--	0.22	0.5	--
Aug 06, 75	1215	40	0.3	--	0.0	0.01	0.00	--	0.27	--	--
			1.2	4.6	0.0	0.01	0.00	--	0.31	2.7	--

* Taken from U. S. Geological Survey open-file report.

Table 6

Bolivar Peninsula Test Site Data; Major Constituents*

Date of Collection	Time	Site	Depth (m)	Dissolved Calcium (Ca) (mg/ℓ)	Dissolved Magnesium (Mg) (mg/ℓ)	Dissolved Sodium (Na) (mg/ℓ)	Dissolved Potassium (K) (mg/ℓ)	Bicarbonate (HCO_3) (mg/ℓ)	Dissolved Sulfate (SO_4) (mg/ℓ)	Dissolved Chloride (Cl) (mg/ℓ)	Dissolved Solids (Sum of Constituents) (mg/ℓ)
						Line 610					
Apr 25, 75	1500	40	0.3	150.0	390.0	3400	130	117	850	6000	11000
			4.9	150.0	400.0	3400	140	116	870	6100	11100
Jun 24, 75	1245	40	0.3	140.0	350.0	3100	120	115	760	5400	9930
			4.9	160.0	410.0	3600	180	115	880	6200	11500
Aug 06, 75	1040	40	0.3	--	--	--	--	--	--	--	--
			4.6	290.0	750.0	6600	260	138	1500	11000	20500
						Line 620					
Apr 25, 75	1430	40	0.6	160.0	410.0	3600	140	119	940	6400	11700
Jun 24, 75	1400	40	0.3	150.0	380.0	3300	140	108	950	5800	10800
Aug 06, 75	1245	40	0.5	150.0	360.0	3200	130	128	740	5600	10300
						Line 630					
Apr 25, 75	1415	40	1.1	160.0	410.0	3500	140	117	970	6200	11400
Jun 24, 75	1345	40	0.3	140.0	350.0	3100	130	111	790	5500	10100
Aug 06, 75	1230	40	1.1	--	--	--	--	--	--	--	--
						Line 640					
Apr 25, 75	1330	40	0.3	150.0	400.0	3400	140	119	870	6200	11200
			1.4	150.0	400.0	3400	140	119	770	6000	10900
May 15, 75	0710	40	1.2	--	--	--	--	--	--	--	--
May 15, 75	2010	40	0.6	--	--	--	--	--	--	--	--
Jun 24, 75	1320	40	0.3	140.0	420.0	3100	130	111	780	5500	10100
			1.4	160.0	360.0	3600	150	117	930	6400	11700
Aug 06, 75	1215	40	0.3	--	--	--	--	--	--	--	--
			1.2	250.0	740.0	5900	250	135	1600	11000	19800

* Taken from U. S. Geological Survey open-file report.

Table 7

Bolivar Peninsula Test Site Data; Selected Ions Analyses*

Date of Collection	Time	Site	Depth (m)	Dissolved Aluminum (Al) (μg/ℓ)	Dissolved Arsenic (As) (μg/ℓ)	Total Arsenic (As) (μg/ℓ)	Bottom Deposit Arsenic (As) (μg/g)	Dissolved Cadmium (Cd) (μg/ℓ)	Total Cadmium (Cd) (μg/ℓ)	Bottom Deposit Cadmium (Cd) (μg/g)
					Line 610					
Apr 25, 75	1500	40	0.3	10	0	--	--	0	--	--
			4.9	10	0	--	2	0	--	<10.0
Jun 24, 75	1245	40	0.3	20	1	--	--	0	--	--
			4.9	20	1	--	--	0	--	--
					Line 620					
Apr 25, 75	1430	40	0.6	10	1	--	1	0	--	<10.0
Jun 24, 75	1400	40	0.3	20	1	--	--	0	--	--
					Line 630					
Apr 25, 75	1415	40	1.1	10	1	--	1	0	--	<10.0
Jun 24, 75	1345	40	0.3	9	2	--	--	0	--	--
					Line 640					
Apr 25, 75	1330	40	0.3	0	1	--	--	0	--	--
			1.4	10	1	--	1	0	--	<10.0
Jun 24, 75	1320	40	0.3	6	1	--	--	0	--	--
			1.4	20	1	--	--	0	--	--

(Continued)

* Taken from U. S. Geological Survey open-file report.

Table 7 (Continued)

Date of Collection	Time	Site	Depth (m)	Dissolved Chromium (Cr) (μg/ℓ)	Total Chromium (Cr) (μg/ℓ)	Dissolved Cobalt (Co) (μg/ℓ)	Total Cobalt (Co) (μg/ℓ)	Bottom Deposit Cobalt (Co) (μg/g)	Dissolved Copper (Cu) (μg/ℓ)	Total Copper (Cu) (μg/ℓ)	Bottom Deposit Copper (Cu) (μg/g)
					Line 610						
Apr 25, 75	1500	40	0.3	0	--	0	--	--	4.0	--	--
			4.9	0	--	0	--	<10.0	2.0	--	<10.0
Jun 24, 75	1245	40	0.3	0	--	0	--	--	4.0	--	--
			4.9	0	--	0	--	--	5.0	--	--
					Line 620						
Apr 25, 75	1430	40	0.6	0	--	0	--	<10.0	12.0	--	<10.0
Jun 24, 75	1400	40	0.3	0	--	0	--	--	1.0	--	--
					Line 630						
Apr 25, 75	1415	40	1.1	0	--	0	--	<10.0	2.0	--	<10.0
Jun 24, 75	1345	40	0.3	0	--	0	--	--	4.0	--	--
					Line 640						
Apr 25, 75	1330	40	0.3	0	--	0	--	--	2.0	--	--
			1.4	0	--	0	--	<10.0	6.0	--	<10.0
Jun 24, 75	1320	40	0.3	0	--	0	--	--	1.0	--	--
			1.4	0	--	0	--	--	2.0	--	--

(Continued)

Table 7 (Continued)

Date of Collection	Time	Site	Depth (m)	Dissolved Cyanide (Cn) (mg/ℓ)	Bottom Deposit Cyanide (Cn) (μg/g)	Dissolved Iron (Fe) (μg/ℓ)	Total Iron (Fe) (μg/ℓ)	Bottom Deposit Iron (Fe) (μg/g)	Dissolved Lead (Pb) (μg/ℓ)	Total Lead (Pb) (μg/ℓ)	Bottom Deposit Lead (Pb) (μg/g)
					Line 610						
Apr 25, 75	1500	40	0.3	--	--	40	--	--	0	--	--
			4.9	--	0.0	40	--	--	0	--	<10.0
Jun 24, 75	1245	40	0.3	--	--	40	--	--	0	--	--
			4.9	--	--	40	--	--	0	--	--
					Line 620						
Apr 25, 75	1430	40	0.6	--	0.0	50	--	--	1	--	<10.0
Jun 24, 75	1400	40	0.3	--	--	40	--	--	0	--	--
					Line 630						
Apr 25, 75	1415	40	1.1	--	0.0	50	--	--	1	--	<10.0
Jun 24, 75	1345	40	0.3	--	--	40	--	--	0	--	--
					Line 640						
Apr 25, 75	1330	40	0.3	--	--	40	--	--	0	--	--
			1.4	--	0.0	40	--	--	0	--	<10.0
Jun 24, 75	1320	40	0.3	--	--	40	--	--	0	--	--
			1.4	--	--	40	--	--	0	--	--

(Continued)

Table 7 (Continued)

Date of Collection	Time	Site	Depth (m)	Dissolved Lithium (Li) (μg/ℓ)	Dissolved Manganese (Mn) (μg/ℓ)	Total Manganese (Mn) (μg/ℓ)	Bottom Deposit Manganese (Mn) (μg/g)	Dissolved Mercury (Hg) (μg/ℓ)	Total Mercury (Hg) (μg/ℓ)	Bottom Deposit Mercury (Hg) (μg/g)	Dissolved Nickle (Ni) (μg/ℓ)	Dissolved Strontium (Sr) (μg/ℓ)
						Line 610						
Apr 25, 75	1500	40	0.3	60	10	--	--	0.3	--	--	0	2400
			4.9	50	10	--	140	0.1	--	0.9	1	2300
Jun 24, 75	1245	40	0.3	50	10	--	--	0.0	--	--	0	2100
			4.9	60	10	--	--	0.0	--	--	0	2400
						Line 620						
Apr 25, 75	1430	40	0.6	50	10	--	50	0.1	--	0.7	4	2500
Jun 24, 75	1400	40	0.3	60	10	--	--	0.0	--	--	0	2200
						Line 630						
Apr 25, 75	1415	40	1.1	50	10	--	70	0.1	--	1.3	1	2400
Jun 24, 75	1345	40	0.3	50	10	--	--	0.0	--	--	1	--
						Line 640						
Apr 25, 75	1330	40	0.3	50	10	--	--	0.2	--	--	0	2300
			1.4	50	10	--	80	0.1	--	1.3	1	2300
Jun 24, 75	1320	40	0.3	50	10	--	--	0.0	--	--	0	2100
			1.4	60	10	--	--	0.0	--	--	1	2300

(Continued)

(Sheet 4 of 5)

Table 7 (Concluded)

Date of Collection	Time	Site	Depth (m)	Dissolved Zinc (Zn) (μg/ℓ)	Total Zinc (Zn) (μg/ℓ)	Bottom Deposit Zinc (Zn) (μg/g)
				Line 610		
Apr 25, 75	1500	40	0.3	80	--	--
			4.9	40	--	20.0
Jun 24, 75	1245	40	0.3	110	--	--
			4.9	110	--	--
				Line 620		
Apr 25, 75	1430	40	0.6	40	--	<10.0
Jun 24, 75	1400	40	0.3	60	--	--
				Line 630		
Apr 25, 75	1415	40	1.1	60	--	<10.0
Jun 24, 75	1345	40	0.3	110	--	--
				Line 640		
Apr 25, 75	1330	40	0.3	40	--	--
			1.4	40	--	<10.0
Jun 24, 75	1320	40	0.3	30	--	--
			1.4	80	--	--

(Sheet 5 of 5)

Table 8

Bolivar Peninsula Test Site Data; Insecticide and Herbicide Analyses*

Date of Collection	Time	Site	Depth (m)	Total Aldrin (μg/ℓ)	Bottom Deposit Aldrin (μg/kg)	Total Chlordane (μg/ℓ)	Bottom Deposit Chlordane (μg/kg)	Total DDD (μg/ℓ)	Bottom Deposit DDD (μg/kg)	Total DDE (μg/ℓ)	Bottom Deposit DDE (μg/kg)
						Line 610					
Apr 25, 75	1500	40	0.3	0.00	--	0.0	--	0.00	--	0.00	--
			4.9	0.00	0.0	0.0	0.0	0.00	0.0	0.00	0.0
Jun 24, 75	1245	40	0.3	0.00	--	0.0	--	0.00	--	0.00	--
			4.9	0.00	--	0.0	--	0.00	--	0.00	--
Aug 06, 76	1040	40	4.6	--	0.0	--	0.0	--	0.0	--	0.0
						Line 620					
Apr 25, 75	1430	40	0.6	0.00	--	0.0	--	0.00	--	0.00	--
Jun 24, 75	1400	40	0.3	0.00	--	0.0	--	0.00	--	0.00	--
Aug 06, 75	1245	40	0.5	--	0.0	--	0.0	--	0.0	--	0.0
						Line 630					
Apr 25, 75	1415	40	0.3	0.00	--	0.0	--	0.00	--	0.00	--
			1.1	--	0.0	--	0.0	--	0.0	--	0.0
Jun 24, 75	1345	40	0.3	0.00	--	0.0	--	0.00	--	0.00	--
						Line 640					
Apr 25, 75	1330	40	0.3	0.00	--	0.0	--	0.00	--	0.00	--
			1.4	0.00	0.0	0.0	0.0	0.00	0.4	0.00	0.0
Jun 24, 75	1320	40	0.3	0.00	--	0.0	--	0.00	--	0.00	--
			1.4	0.00	--	0.0	--	0.00	--	0.00	--
Aug 06, 75	1215	40	1.2	--	0.0	--	0.0	--	0.0	--	0.0

(Continued)

* Taken from U. S. Geological Survey open-file report.

(Sheet 1 of 5)

Table 8 (Continued)

Date of Collection	Time	Site	Depth (m)	Total DDT (μg/ℓ)	Bottom Deposit DDT (μg/kg)	Total Dieldrin (μg/ℓ)	Bottom Deposit Dieldrin (μg/kg)	Total Endrin (μg/ℓ)	Bottom Deposit Endrin (μg/kg)	Total Heptachlor (μg/ℓ)	Bottom Deposit Heptachlor (μg/kg)
						Line 610					
Apr 25, 75	1500	40	0.3	0.00	--	0.00	--	0.00	--	0.00	--
			4.9	0.00	0.0	0.00	0.1	0.00	0.0	0.00	0.0
Jun 24, 75	1245	40	0.3	0.00	--	0.00	--	0.00	--	0.00	--
			4.9	0.00	--	0.00	--	0.00	--	0.00	--
Aug 06, 75	1040	40	4.6	--	0.0	--	0.0	--	0.0	--	0.0
						Line 620					
Apr 25, 75	1430	40	0.6	0.00	--	0.00	--	0.00	--	0.00	--
Jun 24, 75	1400	40	0.3	0.00	--	0.00	--	0.00	--	0.00	--
Aug 06, 75	1245	40	0.5	--	0.0	--	0.0	--	0.0	--	0.0
						Line 630					
Apr 25, 75	1415	40	0.3	0.00	--	0.00	--	0.00	--	0.00	--
			1.1	--	0.0	--	0.0	--	0.0	--	0.0
Jun 24, 75	1345	40	0.3	0.00	--	0.00	--	0.00	--	0.00	--
						Line 640					
Apr 25, 75	1330	40	0.3	0.00	--	0.00	--	0.00	--	0.00	--
			1.4	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
Jun 24, 75	1320	40	0.3	0.00	--	0.00	--	0.00	--	0.00	--
			1.4	0.00	--	0.00	--	0.00	--	0.00	--
Aug 06, 75	1215	40	1.2	--	0.0	--	0.0	--	0.0	--	0.0

(Continued)

Table 8 (Continued)

Date of Collection	Time	Site	Depth (m)	Total Heptachlor Epoxide (μg/ℓ)	Bottom Deposit Heptachlor Epoxide (μg/kg)	Total Lindane (μg/ℓ)	Bottom Deposit Lindane (μg/kg)	Total Parathion (μg/ℓ)	Total Methyl Parathion (μg/ℓ)	Total Malathion (μg/ℓ)	Total Diazinon (μg/ℓ)
Line 610											
Apr 25, 75	1500	40	0.3	0.00	--	0.00	--	0.00	0.00	0.00	0.00
			4.9	0.00	0.0	0.00	--	0.00	0.00	0.00	0.00
Jun 24, 75	1245	40	0.3	0.00	--	0.00	--	0.00	0.00	0.00	0.00
			4.9	0.00	--	0.00	--	0.00	0.00	0.00	0.10
Aug 06, 75	1040	40	4.6	--	0.0	--	0.0	--	--	--	--
Line 620											
Apr 25, 75	1430	40	0.6	0.00	--	0.00	--	0.00	0.00	0.00	0.00
Jun 24, 75	1400	40	0.3	0.00	--	0.00	--	0.00	0.00	0.00	0.00
Aug 06, 75	1245	40	0.5	--	0.0	--	0.0	--	--	--	--
Line 630											
Apr 25, 75	1415	40	0.3	0.00	--	0.00	--	0.00	0.00	0.00	0.00
			1.1	--	0.0	--	0.0	--	--	--	--
Jun 24, 75	1345	40	0.3	0.00	--	0.00	--	0.00	0.00	0.00	0.00
Line 640											
Apr 25, 75	1330	40	0.3	0.00	--	0.00	--	0.00	0.00	0.00	0.00
			1.4	0.00	0.0	0.00	--	0.00	0.00	0.00	0.00
Jun 24, 75	1320	40	0.3	0.00	--	0.00	--	0.00	0.00	0.00	0.00
			1.4	0.00	--	0.00	--	0.00	0.00	0.00	0.00
Aug 06, 75	1215	40	1.2	--	0.0	--	0.0	--	--	--	--

(Continued)

Table 8 (Continued)

Date of Collection	Time	Site	Depth (m)	Total PCB (μg/ℓ)	Bottom Deposit PCB (μg/kg)	Total 2,4-D (μg/ℓ)	Bottom Deposit 2,4-D (μg/kg)	Total 2,4,5-T (μg/ℓ)	Bottom Deposit 2,4,5-T (μg/kg)	Total Silvex (μg/ℓ)	Bottom Deposit Silvex (μg/kg)
					Line 610						
Apr 25, 75	1500	40	0.3	0.0	--	0.00	--	0.00	--	0.00	--
			4.9	0.0	--	0.00	0.0	0.00	0.0	0.00	0.0
Jun 24, 75	1245	40	0.3	0.0	--	0.01	--	0.01	--	0.00	--
			4.9	0.0	--	0.01	--	0.01	--	0.00	--
Aug 06, 75	1040	40	0.3	--	--	0.02	--	0.01	--	0.00	--
			4.6	--	0.0	--	--	--	--	--	--
					Line 620						
Apr 25, 75	1430	40	0.6	0.0	--	0.00	--	0.00	--	0.00	--
Jun 24, 75	1400	40	0.3	0.0	--	0.00	--	0.00	--	0.00	--
Aug 06, 75	1245	40	0.5	--	0.0	0.02	--	0.00	--	0.00	--
					Line 630						
Apr 25, 75	1415	40	0.3	0.0	--	0.00	--	0.00	--	0.00	--
			1.1	--	0.0	--	0.0	--	0.0	--	0.0
Jun 24, 75	1345	40	0.3	0.0	--	0.01	--	0.01	--	0.00	--
			1.2	--	--	0.01	--	0.00	--	0.00	--
					Line 640						
Apr 25, 75	1330	40	0.3	0.0	--	0.00	--	0.00	--	0.00	--
			1.4	0.0	--	0.00	0.0	0.00	0.0	0.00	0.0
Jun 24, 75	1320	40	0.3	0.0	--	0.00	--	0.01	--	0.00	--
			1.4	0.0	--	0.01	--	0.01	--	0.00	--
Aug 06, 75	1215	40	0.3	--	--	0.02	--	0.01	--	0.00	--
			1.2	--	0.0	--	--	--	--	--	--

(Continued)

Table 3 (Concluded)

Date of Collection	Time	Site	Depth (m)	Total Toxaphene (μg/ℓ)	Bottom Deposit Toxaphene (μg/kg)	Total Ethion (μg/ℓ)	Bottom Deposit Ethion (μg/kg)	Total Methyl Trithion (μg/ℓ)	Bottom Deposit Methyl Trithion (μg/kg)	Total Trithion (μg/ℓ)	Bottom Deposit Trithion (μg/kg)
					Line 610						
Apr 25, 75	1500	40	0.3	0.0	--	--	--	--	--	--	--
			4.9	0.0	0.0	--	--	--	--	--	--
Jun 24, 75	1245	40	0.3	0.0	--	--	--	--	--	--	--
			4.9	0.0	--	--	--	--	--	--	--
Aug 06, 75	1040	40	4.6	--	0.0	--	--	--	--	--	--
					Line 620						
Apr 25, 75	1430	40	0.6	0.0	--	--	--	--	--	--	--
Jun 24, 75	1400	40	0.3	0.0	--	--	--	--	--	--	--
Aug 06, 75	1245	40	0.5	--	0.0	--	--	--	--	--	--
					Line 630						
Apr 25, 75	1415	40	0.3	0.0	--	--	--	--	--	--	--
			1.1	--	0.0	--	--	--	--	--	--
Jun 24, 75	1345	40	0.3	0.0	--	--	--	--	--	--	--
					Line 640						
Apr 25, 75	1330	40	0.3	0.0	--	--	--	--	--	--	--
			1.4	0.0	0.0	--	--	--	--	--	--
Jun 24, 75	1320	40	0.3	0.0	--	--	--	--	--	--	--
			1.4	0.0	--	--	--	--	--	--	--
Aug 06, 75	1215	40	1.2	--	0.0	--	--	--	--	--	--

(Sheet 5 of 5)

Table 9

Bolivar Peninsula Test Site Data; Organic Carbon Analyses*

Date of Collection	Time	Site	Depth m	Dissolved Organic Carbon mg/ℓ	Suspended Organic Carbon mg/ℓ	Total Organic Carbon mg/ℓ
			Line 610			
Apr 25, 75	1500	40	0.3	5.9	1.2	7.1
			4.9	7.3	1.1	8.4
Jun 24, 75	1245	40	0.3	--	--	9.4
			4.9	--	--	6.8
Aug 6, 75	1040	40	0.3	7.0	0.6	7.6
			4.6	5.8	0.8	6.6
			Line 620			
Apr 25, 75	1430	40	0.6	5.0	1.4	6.4
Jun 24, 75	1400	40	0.3	--	--	6.2
Aug 6, 75	1245	40	0.5	7.0	0.7	7.7
			Line 630			
Apr 25, 75	1415	40	1.1	5.9	1.3	7.2
Jun 24, 75	1345	40	0.3	--	--	9.8
Aug 6, 75	1230	40	1.1	15	1.0	16
			Line 640			
Apr 25, 75	1330	40	0.3	6.4	1.3	7.7
			1.4	8.8	--	--
Jun 24, 75	1320	40	0.3	--	--	12
			1.4	--	--	11
Aug 6, 75	1215	40	0.3	6.8	0.6	7.4
			1.2	9.0	0.7	9.7

* Taken from U. S. Geological Survey open-file report.

Table 10

Bolivar Peninsula Test Site Data; Radiochemical Analyses*

Collection	Time	Site	Depth m	Dissolved RA-226, Radon Method pc/ℓ	Dissolved Uranium (U) µg/ℓ	Dissolved Gross Alpha as U-NAT µg/ℓ	Dissolved Gross Beta as SR 90/Y 90 pc/ℓ	Dissolved Gross Beta as CS-137 pc/ℓ
					Line 610			
Apr 25, 75	1500	40	4.9	0.18	1.1	<95	85	110
					Line 640			
Apr 25, 75	1330	40	1.4	0.18	1.2	<97	130	170

Collection	Time	Site	Depth m	Total Filterable Residue mg/ℓ	Suspended Gross Alpha as U-NAT µg/ℓ	Suspended Gross Beta as SR 90/Y 90 pc/ℓ	Suspended Gross Beta as CS-137 pc/ℓ	Total Non-filterable Residue mg/ℓ
					Line 610			
Apr 25, 75	1500	40	4.9	13,000	0.9	0.6	0.7	15
					Line 640			
Apr 25, 75	1330	40	1.4	13,000	2.0	1.6	1.8	14

* Taken from U. S. Geological Survey open-file report.

Table 11

Current Velocity and Gage Height Observations at Bolivar Peninsula Test Site, 14-16 May 1975*

Line 620, Site 40

Date	Hour	Average Velocity cm/sec	Gage Height cm
May 14	1405	12.19 SW*	58.22
	1510	17.98 SW	59.74
	1600	17.98 SW	59.74
	1710	7.92 SW	55.17
	1800	10.97 SW	56.69
	1900	13.11 SW	56.69
	2005	23.47 SW	55.71
	2100	--	--
	2200	--	--
	2300	--	--
	2400	--	--

Line 640, Site 40

Date	Hour	Average Velocity cm/sec	Gage Height cm	Date	Hour	Average Velocity cm/sec	Gage Height cm
May 14	1425	16.15 SW	56.69	May 15	0800	3.05 NE	21.64
	1500	17.98 SW	56.69		0930	25.91 NE	27.74
	1610	20.12 SW	58.22		1000	27.43 NE	30.78
	1700	15.54 SW	55.71		1100	21.95 NE	35.36
	1805	12.19 SW	56.69		1200	21.03 NE	38.40
	1900	12.19 SW	56.69		1300	20.73 SW	36.88
	2000	23.16 SW	55.71		1400	18.29 SW	38.40
	2100	--	53.64		1500	23.16 NE	42.98
	2200	27.74 SW	58.22		1600	24.69 NE	39.93
	2300	27.74 SW	38.40		1700	27.43 SW	41.45
	2400	30.78 SW	30.78		1800	22.55 SW	39.93
15	0100	29.56 SW	27.74		1900	29.87 SW	38.40
	0200	24.99 SW	21.64		2000	30.78 SW	38.40
	0300	22.25 SW	15.54		2100	38.10 SW	33.83
	0400	27.12 SW	9.45		2200	32.00 SW	30.78
	0500	25.60 SW	7.92		2300	32.92 SW	26.21
	0600	24.38 SW	7.92		2400	25.91 SW	18.59
	0700	20.42 SW	12.50	16	0100	28.35 SW	12.50

* SW--flow southwesterly; NE--flow northeasterly.

Table 12

Current Velocity and Gage Height Observations at Bolivar Peninsula Test Site, 25-26 June 1975*

Line 620, Site 40				Line 640, Site 40			
Date	Hour	Average Velocity cm/sec	Gage Height cm	Date	Hour	Average Velocity cm/sec	Gage Height cm
Jun 25	1315	10.06 NE*	62.79	Jun 25	1300	14.02 NE	62.79
	1400	12.50 NE	64.31		1405	11.28 NE	64.31
	1505	7.62 NE	64.31		1500	9.14 NE	64.31
	1605	8.53 SW	61.26		1600	11.58 NE	61.26
	1710	8.23 SW	58.22		1700	13.41 NE	59.74
	1800	7.92 SW	53.64		1805	17.37 SW	52.12
	1945	9.75 SW	47.55		1920	15.85 SW	50.60
	2000	--	--		2000	19.81 SW	47.55
	2100	8.53 SW	41.45		2100	15.24 SW	41.45
	2200	7.92 SW	33.83		2210	14.02 SW	33.83
	2310	2.74 SW	29.26		2300	16.15 SW	29.26
	2400	0.00	26.21		--	--	--
26	--	--	--	26	0010	12.80 SW	24.69
	0100	--	--		0100	5.79 SW	23.16
	0200	--	--		0200	5.49 SW	21.64
	0300	--	--		0300	4.27 NE	23.16
	0400	--	--		0400	6.71 NE	24.69
	0510	11.58 NE	30.78		0500	15.85 NE	30.70
	0610	7.92 NE	35.36		0600	19.81 NE	35.36
	0705	5.49 NE	46.02		0700	19.51 NE	46.02
	0810	10.58 NE	42.98		0800	18.29 NE	42.98
	0900	10.36 NE	52.12		0905	14.02 NE	52.12
	1005	10.67 NE	49.07		1000	12.19 NE	49.07
	1100	10.67 NE	52.12		1105	9.75 NE	52.12
	1205	12.19 NE	50.60		1200	8.23 NE	50.60

* SW--flow southewesterly; NE--flow northeasterly.

Table 13

Deviations from Mean Water Stage Due to Wind
Galveston Bay at Hanna Reef, 1974*

Wind Velocity km/hr	Deviation, m							
	North	Northeast	East	Southeast	South	Southwest	West	Northwest
16-23	0.15	<0.15	<0.15	<0.15	<0.15	<0.15	0.15-0.30	0.15-0.30
24-32	0.15-0.30	0.15-0.30	--	0.15	<0.15	0.30	0.15-0.30	--
>32	--	--	--	0.15-0.30	--	--	0.30-0.45	--
Direction of stage change	down	down	either	up	up	up	either	down
Days Compared	17	17	11	45	26	2	3	10

* Adapted from U. S. Geological Survey open-file report.

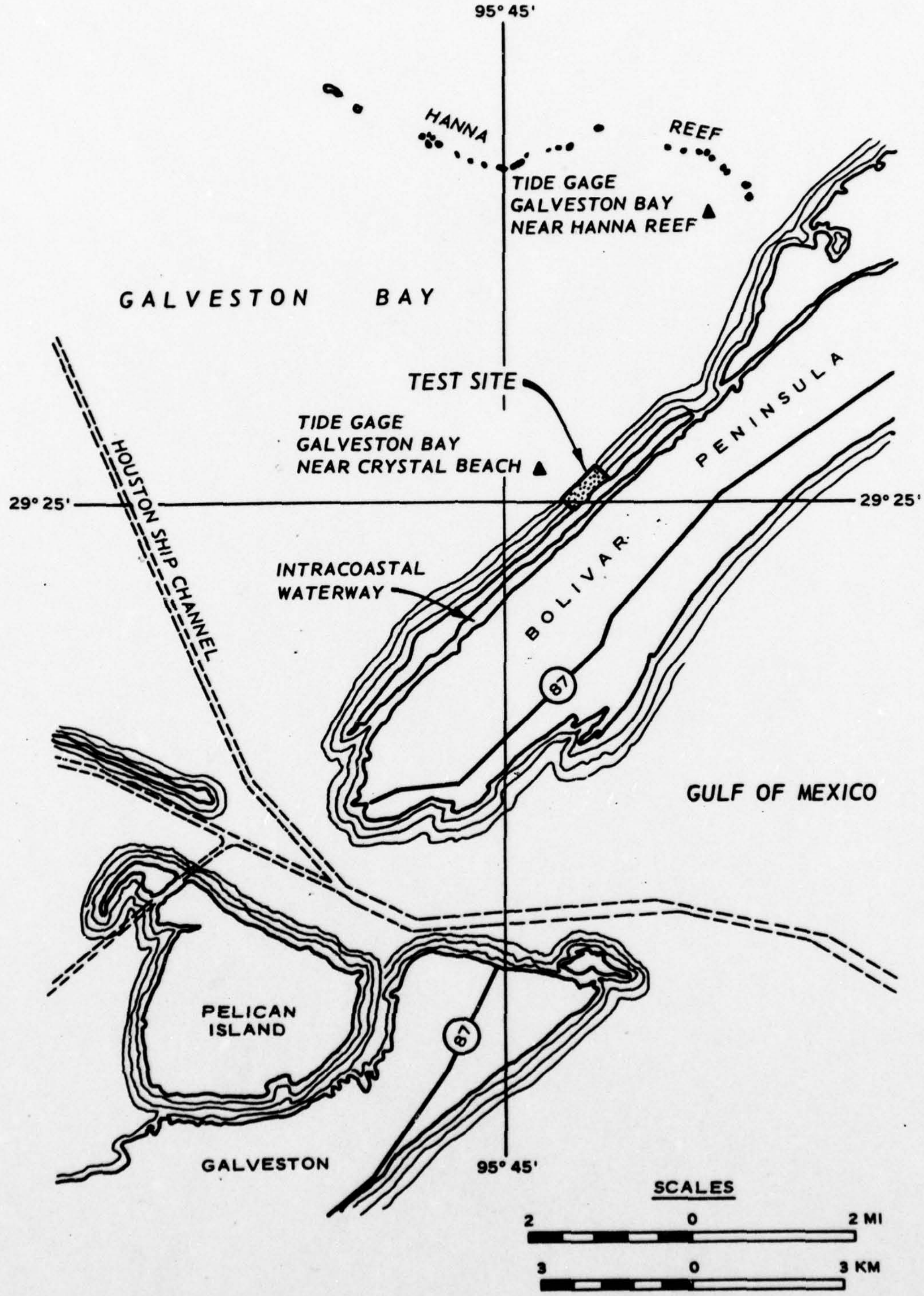


Figure 1. Location of the Bolivar Peninsula test site (taken from the U. S. Geological Survey open-file report)

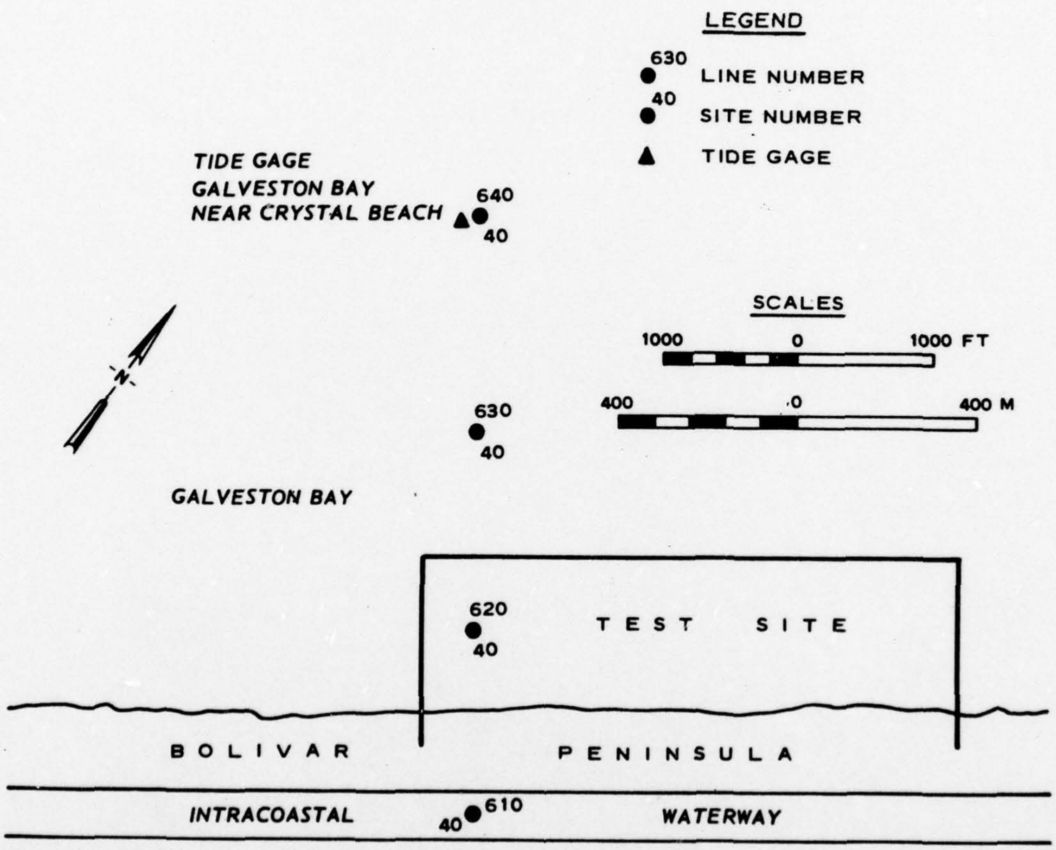
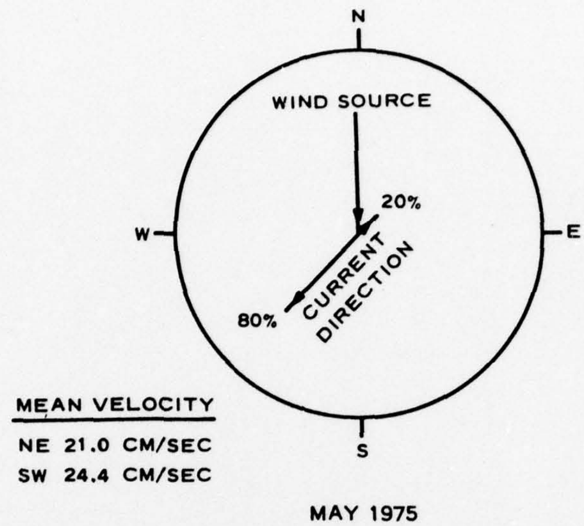


Figure 2. Sampling locations at the Bolivar Peninsula test site (taken from the U. S. Geological Survey open-file report)



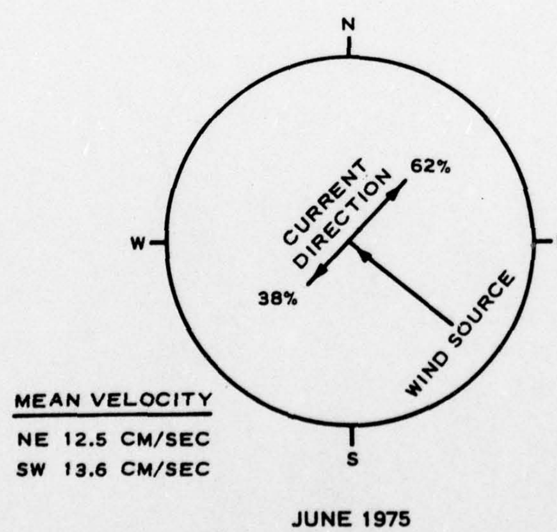
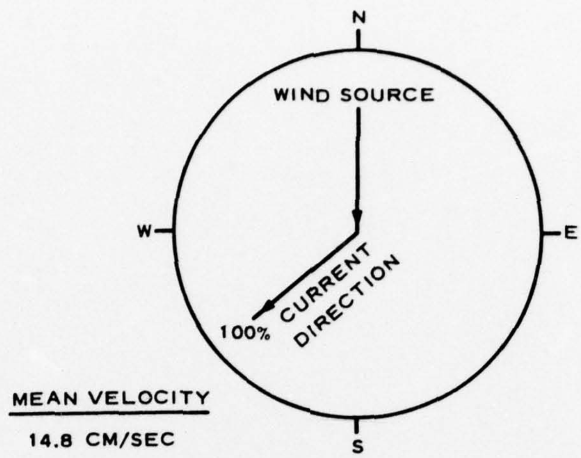
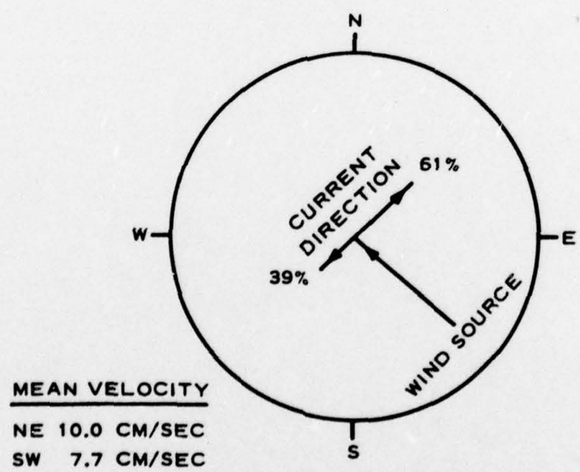


Figure 3. Comparison of water velocities and directions at line 640, site 40 (offshore)



MAY 1975



JUNE 1975

Figure 4. Comparison of water velocities and directions at line 620, site 40 (nearshore)

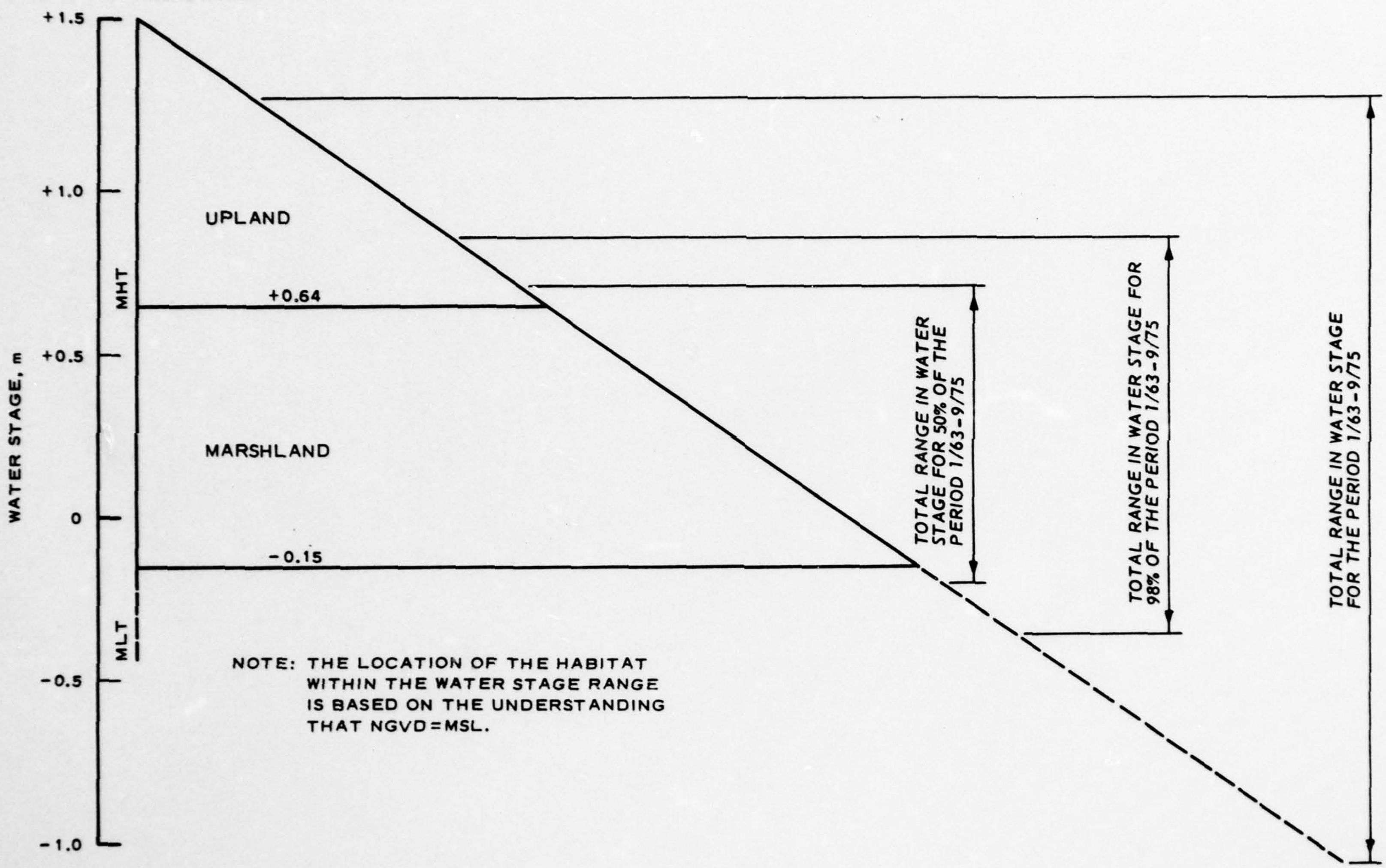


Figure 5. Proposed habitat location in the historical water stage range

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Lunz, John D

Habitat development field investigations, Bolivar Peninsula marsh and upland habitat development site, Galveston Bay, Texas; Appendix A: Baseline inventory of water quality, sediment quality, and hydrodynamics / by John D. Lunz, Ellis J. Clairain, Jr., John W. Simmers. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1978.

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1. Bolivar Peninsula. 2. Dredged material. 3. Field investigations. 4. Galveston Bay. 5. Habitat development. 6. Habitats. 7. Hydrodynamics. 8. Marshes. 9. Sediment. 10. Water quality. I. Clairain, Ellis J., joint author. II. Simmers, John W., joint author. III. United States. Army. Corps of Engineers. IV. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; D-78-15, Appendix A.

TA7.W34 no.D-78-15 Appendix A

DREDGED MATERIAL RESEARCH PROGRAM

TECHNICAL REPORT D-78-15

HABITAT DEVELOPMENT FIELD INVESTIGATIONS BOLIVAR PENINSULA MARSH AND UPLAND HABITAT DEVELOPMENT SITE GALVESTON BAY, TEXAS

APPENDIX B: BASELINE INVENTORY OF TERRESTRIAL FLORA, FAUNA, AND SEDIMENT CHEMISTRY

by

J. D. Dodd, D. J. Herlocker, B. W. Cain
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College of Agriculture
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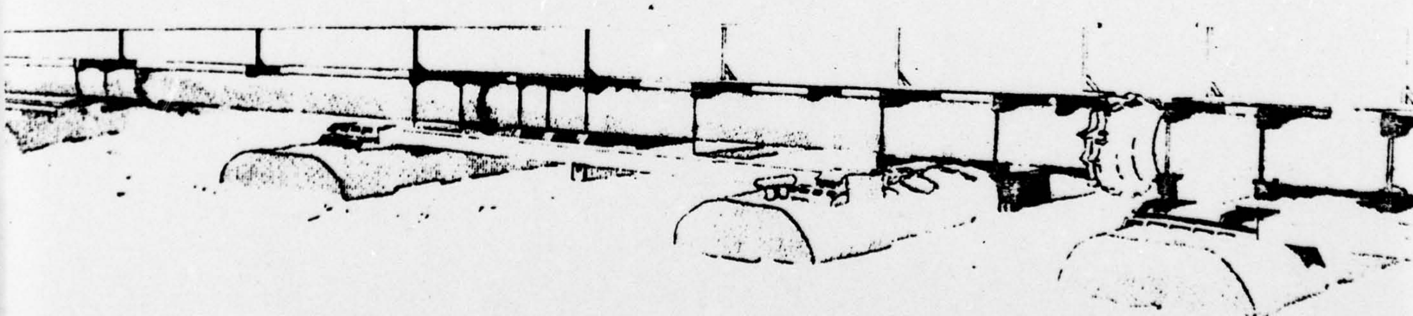
May 1978

Final Report



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HABITAT DEVELOPMENT FIELD INVESTIGATIONS, BOLIVAR PENINSULA
MARSH AND UPLAND HABITAT DEVELOPMENT SITE
GALVESTON BAY, TEXAS

Appendix A: Baseline Inventory of Water Quality, Sediment Quality, and Hydrodynamics

Appendix B: Baseline Inventory of Terrestrial Flora, Fauna, and Sediment Chemistry

Appendix C: Baseline Inventory of Aquatic Biota

Appendix D: Propagation of Vascular Plants and Postpropagation Monitoring of Botanical, Soil, Aquatic Biota, and Wildlife Resources

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B. W. Cain, C. Lindau

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Animals	Galveston Bay	Sediment
Birds	Habitats	Sediment sampling
Bolivar Peninsula	Mammals	Soil chemistry
Dredged material	Marshes	
Field investigations	Plants (Botany)	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study involved collection of flora, fauna, and sediment chemistry baseline data prior to habitat development with dredged material. The specific purposes were to (a) survey and evaluate pertinent historical data and literature; (b) inventory vegetation and prepare a vegetation map; (c) inventory avian, mammal, and macroinvertebrate populations; and (d) determine specific soil chemical properties.

(Continued)

20. ABSTRACT (Continued)

A total of 74 plant species representing 61 genera and 20 families were present at the study site. The dominant grasses were Spartina patens (marshay and Andropogon spp. (bluestem). Forb density was over 435,000 plants/acre with Heterotheca subaxillaris (camphorweed) the most common. The Compositae contributed the greatest number of species. A woody plant density of over 3,250 plants/acre occurred. The dominant was Sesbania drummondii (drummond sesbania). The only other woody species that occurred was Croton punctatus (gulf croton). Standing crop biomass production on the study site exceeded 3,000 pounds/acre. The following six major plant communities were mapped, in order of area occupied: (a) Andropogon perangustatus, (b) Spartina patens, (c) Sesbania-mixed grass, (d) Sporobolus virginicus-Distichlis spicata, (e) Monarda citriodora, and (f) Spartina alterniflora.

A total of 98 bird species were identified, with red-winged blackbirds the most numerous species. Thirteen mammal species were recorded, 3 of them domestic. The most common were hispid cotton rat, raccoon, and domestic goat. A total of 31 individuals representing 11 species of reptiles and amphibians were observed. Eighteen orders of macroinvertebrates were collected and identified.

Soil and sediment samples were sandy in texture to a depth of 107 cm. Total organic carbon was generally less than 0.2 percent. Extractable ammonium and extractable orthophosphate varied but were present in low quantities. Values of Eh varied from +500 mv for oxidized horizons to near -240 mv in the intertidal area. The pH values of the sediments ranged from 7.00 to 8.50. Interstitial water did not contain excessive concentrations of ammonium-, nitrite- or nitrate-nitrogen. Total inorganic nitrogen never exceeded 6.14 mg/ℓ. Total phosphorus and orthophosphate concentrations were less than 3.25 and 0.625 mg/ℓ, respectively. Total dissolved carbon ranged between 2.0 and 9.55 mg/ℓ. Excessive nutrient concentrations were not found in this series of core samples. Metal concentrations of lowland interstitial water were similar to those interstitial water values from the profiles located in the intermediate areas. Magnesium, potassium, sodium, and calcium concentrations for interstitial water from the lowland areas were high compared to those for the intermediate sites. Heavy metal concentrations (iron, manganese, zinc, copper, lead, cadmium, and mercury) were low.

SUMMARY

This study involved the collection of flora, fauna, and sediment chemistry baseline data prior to habitat development with dredged material. The specific purposes were to (a) survey and evaluate pertinent historical data and literature; (b) inventory vegetation and prepare a vegetation map; (c) inventory avian, mammal, and macroinvertebrate populations; and (d) determine specific soil chemical properties.

Seventy-four plant species representing 61 genera and 20 families were collected and identified. Vegetation of the study area had a basal cover of 13.2 percent and a litter cover of 15.8 percent. The Gramineae and Cyperaceae families accounted for most of the basal cover. *Spartina patens* (marshay)* and *Andropogon* spp. (bluestem) were the dominant grasses. Forb density on the study area was 437,778 plants/acre. The Compositae contributed more plants to forb density than any other family. *Heterotheca subaxillaris* (camphorweed) had the highest relative density and frequency. Woody plant species had a density of 3,279 plants/acre. September biomass production was 3,071 pounds/acre for the study area; bluestem and marshay dominated with 30.8 percent and 28.7 percent of the total production, respectively.

Six plant communities were delineated on the basis of basal cover by dominants. These were: (a) *Andropogon perangustatus*, (b) *Spartina patens*, (c) *Sesbania*-mixed grass, (d) *Sporobolus virginicus-Distichlis spicata*, (e) *Monarda citriodora*, and (f) *Spartina alterniflora*. The *Andropogon perangustatus* and *Spartina patens* communities were the most extensive accounting for 37 percent and 25 percent of the study area, respectively. Each also produced over 4,100 pounds/acre biomass.

Forty-one bird species were recorded on the site during July, and the number increased to 50 in September. Overall the total was 98, with red-winged blackbirds the most numerous species. Thirteen mammal species were recorded on the site (three of them domestic), and the most common species were raccoon, hispid cotton rat, and domestic goat. There were

* This grass is also known as saltmeadow cordgrass in other regions of the nation.

11 species of reptiles and amphibians observed represented by a total of 31 individuals. Eighteen orders of macroinvertebrates were collected and identified. The most common forms were grasshopper, land snail, mud fiddler crab, and tiger beetle.

Soil and sediment samples were all sandy in texture to a depth of 107 cm. The least amount of sand reported at any depth was 88 percent. Total organic carbon was generally less than 0.2 percent. Extractable ammonium and orthophosphate were variable but generally present in low quantities. Values of Eh varied from +500 mv for oxidized horizons located in the upland region to near -240 mv in the intertidal area. The Eh was closely related to moisture content. The pH values of the sediments ranged from 7.00 to 8.50.

Interstitial water samples did not contain excessive concentrations of ammonium-, nitrite-, or nitrate-nitrogen. Total inorganic nitrogen never exceeded 6.14 mg/ℓ and was generally much lower. Total phosphorous and orthophosphate concentrations were less than 3.25 and 0.625 mg/ℓ, respectively. Total dissolved carbon ranged between 2.0 and 9.55 mg/ℓ.

Chemical composition of the sediments generally corresponded to the sandy nature of the material. Excessive nutrient concentrations were not found in this series of core samples. Metal concentrations of lowland interstitial water are similar to those interstitial water values from the profiles located in the intermediate areas. Magnesium, potassium, sodium, and calcium concentrations for interstitial water from the lowland areas were high compared to the intermediate sites. Heavy metal concentrations (iron, manganese, zinc, copper, lead, cadmium, and mercury) were low.

PREFACE

This report presents the results of an investigation to describe quantitatively the flora, fauna, and sediment chemistry of a disposal site on Bolivar Peninsula, Galveston Bay, Texas. The investigation was conducted as a part of the Corps of Engineers' Dredged Material Research Program (DMRP) under Contract No. DACW64-75-C-0101, entitled "Inventory and Assessment of Terrestrial Flora, Fauna, and Sediment Chemistry at Bolivar Peninsula Habitat Development Site, Galveston Bay, Texas, dated 12 June 1975, between the U. S. Army Engineer District, Galveston, and the College of Agriculture, Texas A&M University, College Station, Texas. The DMRP was sponsored by the Office, Chief of Engineers, U. S. Army, and was monitored by the Environmental Laboratory (EL) of the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss. The Galveston District administered the contract for WES. Contracting Officer was COL D. S. McCoy, CE.

Parts I, II, III, IV, and VII were prepared by D. J. Herlocker and J. D. Dodd, Research Associate and Professor, respectively, in Range Science, Texas A&M University. B. W. Cain and B. J. Lee, Assistant Professor and Research Assistant, respectively, in Wildlife and Fisheries Sciences, Texas A&M University, prepared Part V. "Sediment Chemistry," Part VI, was prepared by L. R. Hossner and C. Lindau, Associate Professor and Research Assistant, respectively, in Soil and Crop Sciences, Texas A&M University.

The contract monitors at WES were J. S. Boyce and H. H. Allen, EL. Project manager was H. K. Smith, Manager, Habitat Development Project, EL. John Harrison was Chief, EL.

The authors express appreciation to personnal of WES and the Galveston District for their cooperation during this project. Special appreciation is extended to S. L. Hatch and F. Waller for their assistance in plant identification.

COL G. H. Hilt, CE, and COL J. L. Cannon, CE, were Directors of WES during the conduct of the contract and the preparation of this report. Mr. F. R. Brown was Technical Director.

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CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	2.54	centimetres
feet	0.3048	metres
miles (U.S. statute)	1.609344	kilometres
square feet	0.09290304	square metres
square miles (U.S. statute)	2.589988	square kilometres
acres	4046.856	square metres
cubic yards	0.7645549	cubic metres
pounds (mass)	0.4535924	kilograms
miles (U.S. statute) per hour	1.609344	kilometres per hour

BASELINE INVENTORY OF TERRESTRIAL
FLORA, FAUNA, AND SEDIMENT CHEMISTRY

PART I: INTRODUCTION

1. Coastal marsh comprises 1,250 square miles* and is the most important land resource area on the Texas coast (Godfrey et al. 1973). Marsh is important in flood control and water quality, provides excellent wildlife habitat, and is a valuable source of nutrients for livestock and marine life (National Aeronautics and Space Administration (NASA) 1974). One-third of the population and nearly one-third of the industry of Texas is located on the Gulf coast (Fisher et al. 1972). This has had a serious impact on coastal marshes. Hundreds of acres are filled each year and the land use changed (NASA 1974). Thus, it is important to consider ways and means of maintaining and/or reestablishing marsh.

2. Approximately 2.3 percent of the coast marsh resource area has been set aside for dredged material sites (U.S. Army Corps of Engineers (USCE) 1975a). These sites provide substrates for marsh development (especially open-water sites, which comprise about 48 percent of the total). In these areas, few other competitive land uses exist. Thus, an opportunity is provided to investigate the feasibility of marsh establishment on dredged material disposal sites.

3. This study involves the feasibility of using dredged material as a substrate for development of salt marshes along the upper Texas coast. Phase I involves collection of baseline data prior to development. Objectives include (a) survey and evaluation of historical data and literature pertinent to the study site, (b) inventory of avian, mammal, and macroinvertebrate populations inhabiting the study site, (c) inventory of vegetation including preparation of a vegetation map, and (d) determination of specific soil chemical properties of the study area prior to deposition of dredged material.

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*A table of factors for converting U.S. customary units of measurements to metric (SI) units is given on page 9.

PART II: DESCRIPTION OF AREA

4. Bolivar Peninsula forms the eastern end of a chain of sand barriers that extend almost 600 miles along the Mexican and Texas coasts. The Bolivar Peninsula has developed as an offshore sand bar since the post-Pleistocene rise in sea level about 4000 years ago (Lankford and Rehkemper 1969). It is maintained by marine sedimentation processes, primarily on the Gulf shore. However, some sediment is also transported by sea water washing over the barrier to the bay (NASA 1974). River-transported sediments are negligible (USCE 1968). The peninsula is typically level with occasional elevations of 5 to 10 feet where old dunes occur (U.S. Geological Survey (USGS) 1954a, 1954b, 1954c, 1962a, 1962b).

5. The Galveston area annually receives about 40 inches precipitation, primarily between May and August. High humidities and moderate temperatures reflect proximity to the Gulf (National Oceanic and Atmospheric Administration (NOAA) 1974). Most of the year, prevailing winds are from the south and southeast (USCE 1968). Average velocity is about 11 mph (Lankford and Rehkemper 1969).

6. North of the Bolivar Peninsula, tides in Galveston Bay average about 6 feet and range about 1 foot in amplitude (0.79-1.81 feet above mean sea level) (USCE 1975b). Prevailing south and southeast winds may raise this level 2-3 feet while north winds may lower it as much as 4 feet (Lankford and Rehkemper 1969).

7. Hurricanes are an important factor in the local climate. Since 1871, five tropical storms and seven hurricanes have passed over or near Bolivar Peninsula. There is a 23-percent chance of hurricane occurrence in any one year (Henry et al. 1975). Storm surge associated with hurricanes strongly influences erosional and depositional processes and often results in barrier washover (Lay and O'Neil 1942, NASA 1974, Henry et al. 1975). Storm surges over 8 feet are common, and surges from 15-20 feet have occurred at Galveston. The Bolivar Peninsula, which lies entirely below 15-foot elevation, is thus a prime area for flooding (Henry et al. 1975).

8. Bolivar Peninsula occurs within a soil association comprising the Harris, Veston, and Galveston soil series (Godfrey et al. 1973). These are saline clayey and loamy soils of marshes and sandy soils of beaches. Heavy, saline clays generally overlain by peat occur under marsh vegetation (Lay and O'Neil 1942).

9. Composition of vegetation primarily reflects topography and ground water salinity. Barrier flat vegetation dominated by Spartina patens (marshay) and S. spartinae (gulf cordgrass) occupies the seeward half of the Peninsula. Two large salt marshes occur on the bay side (NASA 1974).

10. Lists of important plant species have been compiled for marsh vegetation along the Texas coast (Gould 1975) and for eastern Galveston County (Waller 1974). The principal coastal marsh communities of East Texas have been described by Lay and O'Neil (1942). These are: saline marshes, dominated by Spartina alterniflora Loisel. (smooth cordgrass), brackish marshes dominated by marshay and Distichlis spicata (L.) Green (seashore saltgrass), and fresh marshes dominated by Typha angustifolia L. (narrowleaf cattail), T. latifolia L. (common cattail), Scirpus californicus (California bulrush), and Eleocharis quadrangulata (Michx.) R.&S. (squarestem spikesedge).

11. Texas marshes overlie a heavy mineral soil (often saline) topped by a peaty layer. They are generally formed through subsidence (0.2 foot/century in the Galveston area) and lie behind beach ridges that prevent direct influx of seawater except during hurricanes (Lay and O'Neil 1942, Lankford and Rehkemper 1969).

12. Muskrat populations were exploited on Bolivar Peninsula until a few decades ago (Lay and O'Neil 1942). Present land use includes livestock ranching (Lay and O'Neil 1942, NASA 1974), exploitation of oil and natural gas fields (Holstrum and Williams 1971), and permanent and summer residences and commercial establishments (USCE 1968). Oyster beds lie immediately offshore on the bay side. This is also a nursery area for fishes of Galveston Bay. It is used extensively for recreational boating and fishing (USCE 1968, 1970, Holstrum and Williams 1971). In addition, commercial shipping uses the Gulf Intra-Coastal Waterway (GIWW), which runs along the entire bay side of the peninsula. Dredging associated with the GIWW has been almost continuous along this stretch since completion in 1933 (Lay and O'Neil 1942, USCE 1975c). Selected areas are dredged about every 2 years. The average quantity of materials dredged per contract is 1.6 million cubic yards (USCE 1975c).

13. The study site is located on Galveston Bay between Marsh and Baffle Points near the west end of Bolivar Peninsula. It ranges in elevation from -0.2 feet to about +10.0 feet mean sea level (USCE 1975d).

The location is between the GIWW and the bay in dredged material disposal area No. 41. This area has no containing levee system, unlike some other disposal areas (USCE 1970). Dredged material deposition occurs about every 4 years on this site; the last disposal was in 1971.

PART III: PLOT AND SAMPLING DESIGN

14. The study area is rectangular, 2,000 by 600 feet, 27.5 acres in area. Of this, 14 acres is intertidal and supports little vegetation. The study area has been extended back to the GIWW to include upland vegetation communities. This added 14 acres to the total area.

15. A surveyed baseline forms the south edge of the study area (Figure 1). Thirty-nine topographic transects have been established at 50-foot intervals along and at right angles to the baseline and were surveyed to the bay side of the study area. These have been extended nontopographically back to the GIWW. This system of transects was a reference for subsequent surveys of vegetation, soils, and wildlife.

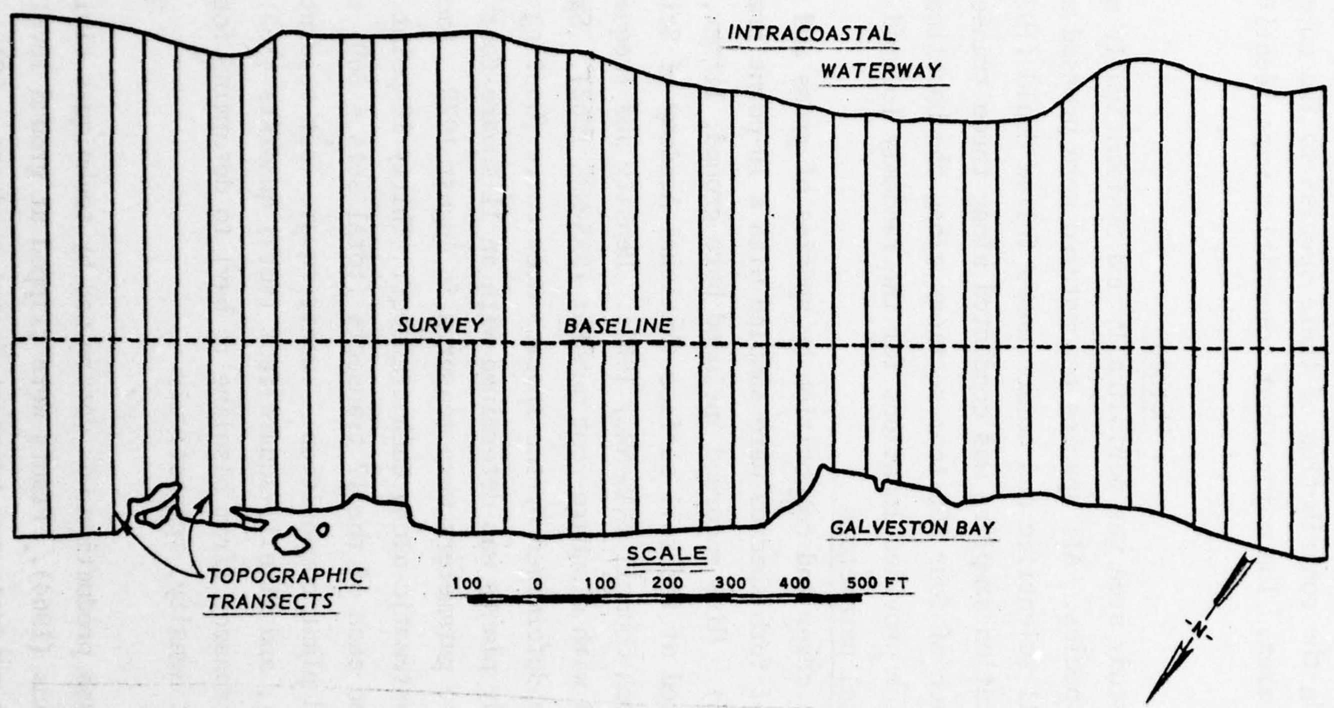

Figure 1. Study area at Bolivar Peninsula. The study area is located between the baseline and Galveston Bay

PART IV: FLORA

16. The purpose of this research was to describe vegetation of the study area quantitatively. This included compiling a species list as well as defining the contribution of these species to the cover and production of the area. The major plant communities were identified and delineated.

Methods

17. The study area was periodically and systematically searched for new plant species. All species encountered were pressed and later identified. All scientific and common names follow Gould (1975).

18. Vegetation sampling was conducted along three transects chosen at random in each of four 500-foot sections along the baseline. The surveyed baseline provided locations for the randomly located transects.

Phytosociological parameters

19. Basal cover and composition by species of grass and sedge, and the abundance of forb species were sampled with a 10-point frame (Levy and Madden 1933). Hits recorded included bare ground, litter, and plant species contacted at the soil surface (National Academy of Science-National Research Council (NAS-NRC) 1962). Density and frequency of forbs were determined with a square-foot quadrat (NAS-NRC 1962). Sample size and number were determined by the species-area curve (Oosting 1956). Density of woody plants was determined with an 11-square-foot quadrat. All of the above parameters were measured in August 1975. Sampling location was systematic along each transect. Thirty 10-point frame sets were utilized on each of the 12 transects (total sets = 360) to determine basal cover and plant composition. Twenty square-foot quadrats (total quadrats = 240), and five 11-square-foot (total quadrats = 60) quadrats were used per transect (from baseline to bay) to determine forb density and woody plant density, respectively.

Biomass

20. Biomass production was determined by techniques similar to Wiegert and Evans (1964). Plants were clipped at ground level on five 5.5-square-foot quadrats per transect (total quadrats = 60). Plant material was separated into important species. The remainder was placed

into miscellaneous categories of grass, sedge, and forb. Plant material on the soil surface was collected and placed in a litter category. All material was dried for 30 hours at 80° C, weighed, and reported as production in pounds per acre. Vegetation sampling and clipping for production were conducted at the close of vegetative growth periods in September and November 1975.

Communities

21. Boundaries between plant communities were visually noted along transects during vegetation sampling. These were used to stratify recorded data into plant communities for further analysis. In addition, a preliminary vegetation map was prepared for the study area. A final vegetation map was prepared by (a) establishing a 50-by-50-foot grid of stakes throughout the study area based on the 39 surveyed transect lines, and (b) using these to reference visually determined boundaries of plant communities. Procedures for mapping generally followed Brown (1954) and Kuchler (1967).

Results

22. A total of 74 species representing 61 genera and 20 families have been collected and identified from the study site (Appendix A'). Over 62 percent of the flora occurred in three families, Gramineae, Cyperaceae, and Compositae (Table 1). This species list is incomplete since vegetation on the study site exhibits considerable seasonal variability. Thus, collection and identification must extend over a full year to ensure that all major species in the flora have been observed.

Basal cover

23. Overall, vegetative basal cover was 13.2 percent, litter was 15.8 percent, and bare soil surface 71 percent in August 1975. Dominance, in terms of high basal cover, was expressed primarily by species of the Gramineae and Cyperaceae (Table 2). Spartina patens (Marshay) and Andropogon perangustatus (bluestem) dominated the vegetation, contributing 20.1 percent and 13.6 percent of the basal cover, respectively. Five other species contributed 5 percent or more. One of these was from the Compositae, Heterotheca subaxillaris (camphorweed). Forb species contributed less to basal cover than did grass or sedge species.

Table 1

Vegetation Composition by Major Families

on the Bolivar Peninsula Study Site

(Sampled in August 1975)

Family	No. Species	Total Flora (%)
Gramineae	22	29.7
Compositae	15	20.3
Cyperaceae	9	12.2
Leguminosae	7	9.5
Euphorbiaceae	3	4.1
Verbenaceae	3	4.1
Chenopodiaceae	2	2.7
Solanaceae	2	2.7
Total	63	85.3

Table 2

Major Species Contributing to the Vegetation of the Bolivar Peninsula Study Site Based on Basal Cover

Species	Common Name	Species Composition (% Basal Cover)	Family
Spartina patens	Marshay	20.1	Gramineae
Andropogon perangustatus	Bluestem	13.6	Gramineae
Fimbristylis carolinianum	Fimbry	8.6	Cyperaceae
Sporobolus virginicus	Seashore dropseed	6.5	Gramineae
Scirpus americanus	American bulrush	5.9	Cyperaceae
Distichlis spicata	Seashore saltgrass	5.4	Gramineae
Heterotheca subaxillaris	Camphorweed	5.0	Compositae
Andropogon glomeratus	Bushy bluestem	3.8	Gramineae
Eragrostis oxylepis	Red lovegrass	2.7	Gramineae
Monarda citriodora	Lemon beebalm	2.5	Labiatae
Paspalum setaceum	Thin paspalum	2.1	Gramineae

Note: Data collected with 10-point frame.

The most important forbs were camphorweed (5 percent), Monarda citriodora (lemon beebalm) (2.5 percent), and Chenopodium ambrosioides (wormseed goosefoot) (1 percent).

Frequency and density

24. Forb density was over 10 plants/square foot (437,738 plants/acre) in August 1975 (Table 3). The ratio of stems to plants was about 1.2 to 1. This indicated that single-stemmed plants were generally characteristic. Camphorweed contributed most to forb density (35.8 percent) and also was the most frequently occurring forb species in the study area (Table 3), indicating uniform distribution. The Compositae contributed more plants to forb density than any other family. The occurrence of colonies (aggregation of individuals of the same species) was not indicated since all important forb species had higher frequencies than relative densities. Wormseed goosefoot showed the greatest divergence between relative density and frequency, indicating uniform dispersal.

25. Only two species of woody plants were collected, Sesbania drummondii (drummond sesbania) and Croton punctatus (gulf croton). Density of woody plants over 2 feet tall was 3,279 plants/acre in August 1975. The most important species was drummond sesbania with 3,117 plants/acre, 95 percent of the total woody plant density. The stem-to-plant ratio of drummond sesbania was about 1.3:1, similar to that for most forb species. A stem-to-plant ratio of about 1.5 for all woody species reflected the numerous stems typical of gulf croton plants.

Biomass

26. Herbage biomass production for the study was area was over 3,070 pounds/acre in September 1975 (Table 4). Bluestem and marshay dominated in contribution to biomass production (30.8 and 28.7 percent of the total, respectively). The relative importance of both species in terms of production (Table 4) was greater than that expressed by basal cover (Table 2). The relative importance of most secondary species was similar for both basal cover and production; exceptions were that Fimbristylis carolinianum (fimbry) was less important for production and camphorweed was more important for production than indicated by basal cover. There

Table 3

Relative Density and Frequency of Occurrence of Important Forb Species on the Bolivar Peninsula Study Site

Scientific Name	Common Name	Family	Absolute Density (No./acre)	Relative Density (%)	Frequency (%)
Heterotheca subaxillaris	Camphorweed	Compositae	156,816	35.8	45.0
Aphanostephus skirrhobasis	Coast dozedaisy	Compositae	65,340	14.9	22.1
Monarda citriodora	Lemon beebalm	Labitae	60,984	13.9	20.4
Erigeron myrionactis	Corpus Christi fleabane	Compositae	56,628	12.9	33.7
Chenopodium ambrosioides	Wormseed goosefoot	Chenopodiaceae	21,780	5.0	29.6
Gaillardia pulchella	Rosering gaillardia	Compositae	17,424	<5.0	8.7
Trifolium sp.		Leguminosae	17,424	<5.0	11.2
Ambrosia psilostachya	Western ragweed	Compositae	13,068	<5.0	15.4

Table 4

Herbage Aerial Biomass Production by Species on the

Bolivar Peninsula Study Site

(Sampled in September 1975)

Species	Common Name	Dry weight (pounds/acre)	Percent of Total
Andropogon perangustatus	Bluestem	945.9	30.8
Spartina patens	Marshay	881.2	28.7
Sporobolus virginicus	Seashore dropseed	125.5	4.1
Scirpus americanus	American bulrush	103.9	3.4
Heterotheca subaxillaris	Camphorweed	101.2	3.3
Andropogon glomeratus	Bushy bluestem	85.0	2.8
Distichlis spicata	Seashore saltgrass	78.3	2.6
Monarda citriodora	Lemon beebalm	71.5	2.3
Fimbristylis carolinianum	Fimbry	64.8	2.1
Eustachys petraea	No common name	39.1	1.3
Spartina alterniflora	Smooth cordgrass	27.0	0.9
Paspalum setaceum	Thin paspalum	18.9	0.6
Misc. grasses		334.6	10.9
Misc. forbs		186.2	6.0
Misc. sedges		8.1	0.2
Total		3,071.2	
Litter		887.9	

were no data available for comparing the September herbage biomass to other areas along Galveston Bay or the gulf coast.

27. The increase in relative importance of bluestem and marshay as expressed by biomass production over basal area was due to the relatively large clone size of some species. This was particularly evident in bluestem. In camphorweed the increase was due to the presence of multiple stems and large leaves.

Community delineation

28. Five major plant communities were delineated in the study area on the basis of species composition (Table 5 and Figure 2). These communities were named according to dominant species and were: (a) *Andropogon perangustatus*, (b) *Spartina patens*, (c) *Sesbania*-mixed grass, (d) *Sporobolus virginicus-Distichlis spicata*, and (e) *Monarda citriodora*. An additional community, dominated by *Spartina alterniflora*, also was apparent but covered only a small area that yielded only limited data.

29. In general, plant communities were clearly evident from both field surveys and vegetation data since each was dominated by species that were not abundant elsewhere (Table 6). Exceptions did occur in both the *Andropogon perangustatus* and *Sesbania*-mixed grass communities. Each contained a number of species important in both communities.

30. The *Andropogon perangustatus* and *Spartina patens* communities were the most extensive within the study area (baseline to bay), contributing 37 and 25 percent of the total study area, respectively (Table 5).

Cover, density, and frequency within communities

31. As shown in Table 6, vegetative basal cover within communities ranged from 7.8 percent (*Sesbania*-mixed grass) and 8 percent (*Monarda citriodora*) to 15.7 percent (*Sporobolus-Distichlis* and *Spartina patens*). Litter cover ranged from 1.9 percent (*Sporobolus-Distichlis*) to over 43 percent (*Monarda citriodora*) (Table 6).

32. The *Sesbania*-mixed grass community had the highest forb density (17.9 plants/square foot), while the *Spartina patens* community had the lowest (3.4 plants/square foot) (Table 7). Forb density of a community varied inversely with the grass basal cover. Low forb densities in the

Table 5

Major Plant Communities and Area Occupied on the Bolivar Peninsula Study Site (Baseline to Bay)

Community	Common Name	Total Area (Acres)	Percent of Total
Andropogon perangustatus	Bluestem	5.0	37
Spartina patens	Marshay	3.4	25
Sesbania-mixed grass	Sesbania	2.3	17
Sporobolus virginicus - *Distichlis spicata*	Seashore dropseed - Seashore saltgrass	2.0	15
Monarda citriodora	Lemon beebalm	0.7	5
Spartina alterniflora	Smooth cordgrass	0.1	1
Total		13.5	

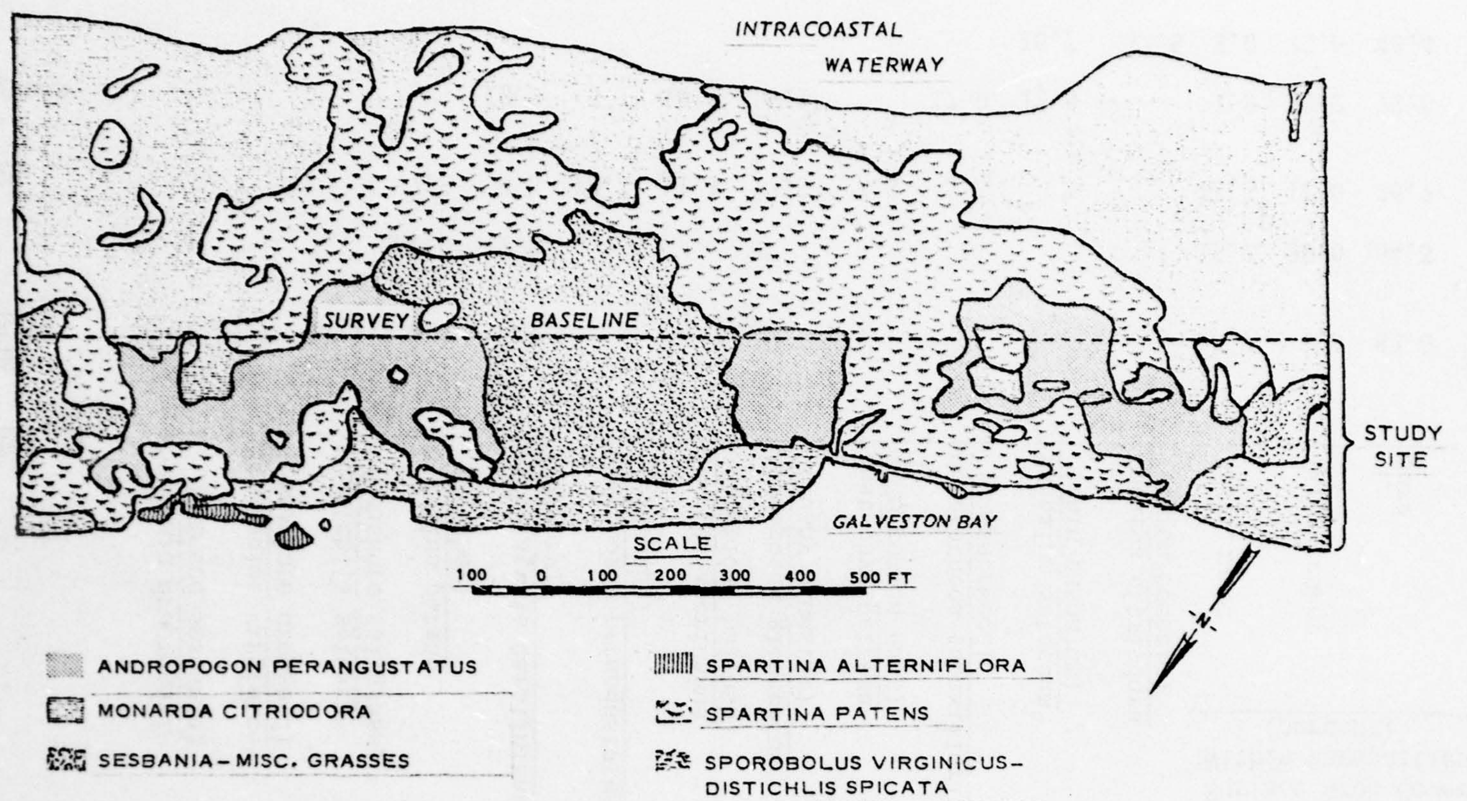

Figure 2. Map of Vegetation Communities on Study Site at Bolivar Habitat Development Site

Table 6

Percent Contribution of Major Species to Total Basal Cover Within Each Plant Community on the Bolivar Peninsula Study Site

Community	Sesbania drummondii (Drummond sesbania)	Sporobolus virginicus (Seashore dropseed)	Distichlis spicata (Seashore saltgrass)	Spartina patens (Marshay)	Fimbristylis carolinianum (Fimbry)	Andropogon perangustatus (Bluestem)	Scirpus americanus (American bulrush)	Andropogon glomeratus (Bushy bluestem)	Eustachys petraea (No common name)	Heterotheca subaxillaris (Camphorweed)	Paspalum setaceum (Thin paspalum)	Monarda citriodora (Lemon beebalm)	Basal cover	Litter cover	Bare
	Species												Surface Area Cover Within Communities (percent)		
Sporobolus-Distichlis	36.0	39.7	33.3	6.4	6.4								15.7	1.9	82.6
Spartina patens				61.0	11.0								15.7	20.0	64.3
Andropogon				7.5	8.8	28.3	11.3	7.5	7.5	6.3			12.3	11.0	76.7
Sesbania-mixed grass					12.8	5.1	10.3	5.1		17.9	12.8		7.8	20.2	72.0
Monarda				8.3							16.7	37.5	8.0	43.6	48.4

Note: Only species with relative basal cover exceeding 5 percent are reported.

Table 7

Percent Contribution to Total Density Within a Plant Community by Major Forb Species on the Bolivar Peninsula Study Site

Community	Species: *Monarda citriodora* (Lemon beebalm)	*Heterotheca subaxillaris* (Camphorweed)	*Chenopodium ambrosioides* (Wormseed goosefoot)	*Erigeron myrionactis* (Corpus Christi fleabane)	Mean Forb Density: Plants/ sq. ft	Plants/ acre
Sesbania-mixed grass		58.2			17.9	779,724
Andropogon		36.9		24.9	11.4	496,584
Monarda	31.1				10.8	470,448
Sporobolus-Distichlis			44.2		4.7	204,732
Spartina patens		35.9			3.4	148,104

Note: Only species with relative densities exceeding 20 percent are reported.

Spartina patens community resulted from the high basal and foliage covers of the dominant species that effectively reduced competition from forb species. The low forb densities in the Sporobolus-Distichlis community were likely related to an extreme environment including high soil salinity, exposure to wind and wave action, and the mat cover resulting from rhizomes of the dominant grasses. High forb densities in the Andropogon perangustatus and Sesbania-mixed grass communities were probably related to the stable mesic environment of the former and the relative lack of perennial grasses in the latter. The Sesbania-mixed grass community appeared to be undergoing rapid plant succession.

33. Differentiation between plant communities on the basis of forb species was more difficult than with grass species. Camphorweed was relatively dense in three communities, particularly the Sesbania-mixed grass community. The Andropogon perangustatus community was the only community with more than one forb species, camphorweed and Erigeron myrionactis (Corpus Christi fleabane), and both species had relative densities exceeding 20 percent.

34. Generally, forb species appeared to have a dispersed pattern. This was particularly true for Ambrosia psilostachya (western ragweed), which had less than 5 percent relative density on the study site (Table 3): in the Spartina patens community it had a 26.9-percent frequency and in the Sporobolus-Distichlis community it had a 24.4-percent frequency (Table 8). However, some colonies did occur. For example, camphorweed had a relative density of 35.9 percent (Table 7) and a frequency of 23.1 percent (Table 8) in the Spartina patens community; wormseed goosefoot had a 44.2-percent relative density (Table 7) and 17.1-percent frequency (Table 8) in the Sporobolus-Distichlis community.

35. The Andropogon perangustatus, Sesbania-mixed grass, and Monarda citriodora communities had high forb frequencies ranging from 51.6 percent in the Monarda community to 62.9 percent in the Andropogon community (Table 8). In addition, a large number of forbs occurred with frequencies exceeding 10 percent. These frequency data were consistent with forb densities in the three communities.

Table 8

Percent Frequency of Occurrence of Major Forb Plant Species Within Each Plant Community on the Bolivar Peninsula Study Site

Community	*Monarda citriodora* (Lemon beebalm)	*Heterotheca subaxillaris* (Camphorweed)	*Chenopodium ambrosioides* (Wormseed goosefoot)	*Erigeron myrionactis* (Corpus Christi fleabane)	*Gaillardia pulchella* (Rosering gaillardia)	*Aphanostephus skirrhobasis* (Coast dozedaisy)	*Ambrosia psilostachya* (Western ragweed)
Sporobolus-Distichlis			17.1				24.4
Spartina patens		23.1					26.9
Andropogon		55.1	33.7	62.9			
Sesbania-mixed grass	37.2	60.8	33.3	37.2			
Monarda	51.6	48.4	35.5	32.3	29.0	29.0	

Note: Only species with frequencies exceeding 20 percent are reported.

Biomass within communities

36. Data on biomass production in September 1975 emphasized the dominant species (based on species composition) in each community. However, based on biomass production, Spartina patens was the dominant in the Sporobolus-Distichlis community (Table 9), even though it occurred in only 2 of the 16 sampled quadrats. The contributions of camphorweed and miscellaneous forbs to biomass production in the Sesbania-mixed grass community suggested inclusion of these species as dominants. This was also true of Spartina patens in the Monarda community: based on total density (Table 7) and frequency of occurrence (Table 8) Spartina patens did not appear as a dominant in the Monarda community, but based on biomass (Table 9) it does. Thus, recognition of plant communities may differ slightly depending upon the criteria used.

37. The Spartina patens and Andropogon perangustatus communities had the greatest per-acre and total biomass production of all communities (Table 9). Although the Andropogon perangustatus community produced less biomass per acre than the Spartina patens community, it contributed the greatest total amount on the site because of the greater area occupied.

38. The Spartina alterniflora and Sesbania-mixed grass communities had the lowest biomass production per acre (Table 9). Thus, they contributed least to the total biomass production of the study area. The low biomass of the Spartina alterniflora community was a result of heavy grazing by goats and sheep. Under protection, biomass from this community would be much higher.

Change in biomass within communities

39. There was little change in the relative biomass production of the major plant communities between September and November (Table 10). Overall, total biomass in November was 9.7 percent less than in the study site in September. Four plant communities had lower standing biomass in November than in September, while two were higher. The increase in biomass from September to November of 625 pounds/acre in the Sesbania-mixed grass community was due to an increase in annual grass species. The two most prominent species were Aristida longespica

Table 9

Percent Contribution of Major Species to Herbage Biomass for Plant Communities on the Bolivar Peninsula Study Site

Community	Species: *Spartina alterniflora* (Smooth cordgrass)	*Sporobolus virginicus* (Seashore dropseed)	*Distichlis spicata* (Seashore saltgrass)	*Spartina patens* (Marshay)	*Andropogon perangustatus* (Bluestem)	*Monarda citriodora* (Lemon beebalm)	*Heterotheca subaxillaris* (Camphorweed)	Misc. grasses	Misc. forbs	Total Community Area (Acres)	Biomass: Pounds per Acre	Total for Community	Percent Total for Site
Spartina patens				84.5						3.4	4459.4	15,162	33.8
Andropogon					58.5			11.5		5.0	4133.8	20,669	46.0
Sporobolus-Distichlis		18.3	13.0	33.9				12.1		2.0	2252.8	4,506	10.0
Monarda				14.6		38.7			20.1	0.7	1874.4	1,312	2.9
Spartina alterniflora	92.8									0.1	1652.2	165	.4
Sesbania-mixed grass					11.0		22.4	28.9	16.8	2.3	1337.6	3,076	6.9

Note: Only species with relative biomass values exceeding 10 percent are reported. Data collected September 1975.

Table 10

Difference between September and November Herbage Biomass

(pounds/acre) for each Community

Community	Difference in Biomass (pounds/acre) between September and November 1975	November Biomass Relative to September Biomass (%)
Spartina patens	-1040	76.7
Andropogon	- 475	88.5
Sporobolus-*Distichlis*	- 293	87.0
Monarda	- 132	93.0
Spartina alterniflora	+1136	168.8
Sesbania-mixed grasses	+ 625	146.8

(slimspike threeawn) and Eragrostis silveana (no common name). The increase measured in Spartina alterniflora community reflects reduced goat grazing in the fall. Decreases in biomass reflected slow growth and the onset of winter dormancy.

40. Litter weight in November was about 25% greater than in the study site in September (Table 11). Three communities, Andropogon, Sporobolus-Distichlis, and Spartina alterniflora increased in litter biomass. In contrast, litter biomass decreased in the Spartina patens, Sesbania-mixed grass, and Monarda communities. The high increase in the Spartina alterniflora community was due to sampling as only one plot occurred in this community and because goats stopped grazing from September until November.

41. The increase of litter biomass in the Andropogon and Sporobolus-Distichlis communities reflected the transfer of stand plant material to litter with the onset of winter dormancy. This correlates with the decrease in standing green biomass in both communities. The Spartina patens community decreased in both living biomass and litter from September to November. This implied a fast turnover (decomposition) of litter. Total litter increased in November from the level in September (Tables 12 and 4), although total production was down slightly. Andropogon perangustatus again contributed the most biomass.

42. A comparison of Tables 9 and 13 shows that in general, miscellaneous grasses increased in importance during the growth period September to November. The only exceptions were the Spartina alterniflora and Sporobolus-Distichlis communities. The increase in miscellaneous grasses in the Monarda community reflected the abrupt decrease in biomass production by Monarda citriodora, the community dominant in September. This decline was associated with establishment and growth of miscellaneous annual grass species. Annual grass species also were established during this period on bare soil in the Sesbania-mixed grasses community.

43. Considerable shift in percent contribution of the major species to community biomass was evident from September to November (Tables 9, 13). Increased biomass measured for Sporobolus virginicus as well as

Table 11

November Litter Biomass as a Percentage of that in September for each Community

Community	Percent of September Litter Biomass
Spartina patens	69.7
Sesbania-mixed grass	77.7
Monarda	96.9
Andropogon	154.0
Sporobolus-Distichlis	256.0
Spartina alterniflora	349.0
Overall for site	125.0

Table 12

Herbage Aerial Biomass Production by Species on the

Bolivar Peninsula Study Site

(Sampled in November 1975)

Species	Common Name	Dry weight (pounds/acre)	Percent of Total
Andropogon perangustatus	Bluestem	613.3	22.2
Spartina patens	Marshay	584.8	21.2
Sporobolus virginicus	Seashore dropseed	288.7	10.4
Scirpus americanus	American bulrush	141.6	5.1
Andropogon glomeratus	Bushy bluestem	124.1	4.4
Fimbristylis carolinianum	Fimbry	82.3	3.0
Heterotheca subaxillaris	Camphorweed	68.8	2.5
Eustachys petraea	No common name	44.5	1.6
Spartina alterniflora	Smooth cordgrass	31.0	1.1
Monarda citriodora	Lemon beebalm	17.5	0.6
Paspalum setaceum	Thin paspalum	6.7	0.2
Misc. grasses		615.3	22.2
Misc. forbs		148.4	5.3
Misc. sedges		6.7	0.2
Total		2773.7	
Litter		1108.9	

Table 13

Percent Contribution of Major Species to Herbage Biomass for Plant Communities on the Bolivar Peninsula Study Site

Community	Species: *Spartina alterniflora* (Smooth cordgrass)	Species: *Sporobolus virginicus* (Seashore dropseed)	Species: *Spartina patens* (Marshay)	Species: *Andropogon perangustatus* (Bluestem)	Species: Misc. grass	Species: Misc. forb	Total Community Area (Acres)	Biomass: Pounds per Acre	Biomass: Total for Community	Biomass: Percent Total for Site
Andropogon				41.9	25.9		5.0	3659	18295	45.5
Spartina patens			65.2		12.3		3.4	3419	11625	29.2
Spartina alterniflora	67.7	32.3					0.1	2788	279	0.7
Sesbania-mixed grasses			22.2		37.6	12.8	2.3	1963	4515	11.3
Sporobolus-Distichlis		49.9	17.0		12.1		2.0	1960	3920	9.8
Monarda			28.9		30.9	17.5	0.7	1742	1219	3.1

Note: Only species with relative biomass values exceeding 10 percent are reported. Data collected November 1975.

the decrease measured for Spartina patens and Distichlis spicata could reflect placement of samples.

44. The map (Figure 2) indicated that vegetation of the study area (baseline to bay) was more heterogeneous than indicated by casual observation. However, the initial plant community boundaries identified by reconnaissance and vegetation sampling were correct. The map indicated more clearly local dominance exhibited by species in areas too small to permit classification as a major community. Differences in vegetative composition reflected a number of environmental factors that influence the occurrence of plant communities: (a) distance from the bay (saline soils and wave and wind action), (b) rooting depth, and (c) age of dredged material deposits. The exact ways these factors influence vegetative composition will have to be determined by specific studies.

PART V: FAUNA

45. In order to determine the response of wildlife populations to habitats created by dredged material disposal, a baseline survey of the affected area must be accomplished prior to habitat alterations. This survey should give data concerning the diversity of animals present and an index to the degree of use of the area before the habitat alterations. Few reports are available on animal colonization of salt marshes established on dredged material (Cammer et al. 1974) or other manmade marshes (Herke 1971). Larimer (1968) discussed the possibilities for creating salt marshes in estuaries along the Atlantic and Gulf coasts.

46. Terrestrial vertebrates in Texas marshes have not been researched unless they were of game or other economic value (Lynch 1967, Chabreck 1972). The avian fauna is censused annually along the Texas coast (Cruickshank 1965-1974), but only recently has analysis of these data been attempted (Lee and Cain in preparation).

Methods

47. Birds. The avifauna were censused by walking five transect lines that divided the study site into four equal areas. These transect lines were about 150 feet apart, running east and west for 2000 feet. Birds were recorded as seen or heard. Birds were surveyed for two hours from half an hour after sunrise on two consecutive mornings twice a month. A literature survey using annual bird counts (Cruickshank 1965-1974) was used to determine residency status.

48. Mammals. Small mammals were trapped on four consecutive nights monthly from October through December 1975. Sherman live traps baited with hen scratch, a nonodiferous prepared feed of primarily milo and corn, were placed in a 7.8-acre grid on the east side of the study site. The grid lines covered all vegetation types and were 50 feet apart, running from bay to waterway. Traps were spaced at 50 feet.

49. Captured small mammals were identified, toe-clipped, aged, sexed, and released at the collection point. Population estimates were made using a modified Schnabel (1938) estimator in the form

$$N = \frac{M\,n}{1 + m} \quad \text{where } N = \text{total population},\ M = \text{total marked animals},\ n = \text{total catch},\ m = \text{recaptures.}$$

This was used so that the time interval between trapping periods was not a factor in population trends.

50. Tomahawk live traps baited with small fish were set for larger mammals. They were also observed indirectly by looking for evidence of their presence (i.e. pellets, tracks, burrows). Goats (Capra hircus) were counted as they visited the study site.

51. Herptiles. Amphibians and reptiles were collected in conjunction with the bird and mammal surveys and with the use of a four-pronged rake to turn over debris. They were identified and released. Population estimates were not made.

52. Invertebrates. Macroinvertebrates, described herein as those invertebrates not passing through a 5-mm mesh screen, were sampled using sweep nets, sieves, a 1-m^2 frame, and a 0.3-m^2 frame. Collections were made on each site visit during July, August, and September 1975, and covered the entire site in a qualitative fashion.

53. Insects were collected by taking 20 sweeps with the net while walking through the herbaceous vegetation. Each sweep conincided with a step, and the area sampled was estimated at 20 m by 1 m for each sample. Five such samples were taken on each site visit. All terrestrial invertebrates were censused by placing a 1-m^2 frame over the vegetation and spraying the enclosed area with a pesticide (Raid for Garden Insects and Pests). The invertebrates were collected from the vegetation as it was clipped and spread out over a paper sack. Crustaceans were censused by placing a 1-m^2 frame on the ground and counting the burrows within the frame. Soil invertebrates were collected and counted by sifting 15 cm of soil from a 0.3-m^2 area through a sieve. Sampling for crustaceans and soil invertebrates was limited to the intertidal zone.

Results

54. Birds. Ninety-eight species were observed. The avian fauna on the site consisted of 41 species during July and increased to

50 species in September (Table 14). The increase in September was due to fall migration. The avifauna decreased in October as some of the summer nesting birds moved south. The increase in November and December is due to the influx of winter residents, especially sparrow species (Table 14).

55. Thirty-four of the bird species sighted are considered permanent residents along the coast of Texas. There were 35 winter residents, 9 summer residents, and 20 migrants. Many of the resident species (19) feed on organisms that are found in Galveston Bay or on its intertidal shores, 12 feed on insects or seeds, and 3 others feed on carrion as well as insects and seeds.

56. Twelve of the species recorded on the site nest in the habitats available on Bolivar Peninsula. The killdeer, willet, and common nighthawks nest on bare areas, the eastern meadowlark uses grass, and the other species (Table 14) nest in the Sesbania or tall herbaceous plants.

57. A qualitative comparison of the beach and upland habitats showed that the upland had fewer species and lower diversity than the beach area. This is at least partly due to the importance of shore and marsh areas in the winter months, the only time this survey was done.

58. Mammals. Mammal diversity on the study site was not high, with only 13 species observed (Table 15), 3 of them domestic. The most common mammals were raccoon, hispid cotton rat, armadillo, and domestic goat. The goats, which wandered across the study site as they grazed on the peninsula, were estimated at 150 in number.

59. The small mammal survey collected 136 hispid cotton rats and 45 house mice. Table 16 gives population estimates.

60. Females composed 33.9% of the cotton rats trapped and males 66.1%, overall. The difference in ratios among months was not significant, but proportionally more males were caught in October than in November and November than in December.

61. Adult cotton rats were more often caught, composing 80% (average) of those captured. The low percentages of juveniles is probably related to the fact that socially subdominant cotton rats

Table 14

Monthly Bird Fauna of the Bolivar Peninsula Study Site

Common Name (Scientific name)		Jul	Aug	Sept	Oct	Nov	Dec
Horned grebe (Podiceps auritus)	(W)	-	-	-	-	+	-
Eared grebe (Podiceps caspicus)	(W)	-	-	-	-	+	+
White pelican (Pelecanus erythrorhynchos)	(F,W)	-	-	-	+	+	+
Double-crested cormorant (Phalacrocorax auritus)	(F,W)	-	-	-	-	+	+
Anhinga (Anhinga anhinga)	(F,W)	-	-	-	+	-	-
Canada goose (Branta canadensis)	(F,W)	-	-	-	-	+	+
White-fronted goose (Anser albifrons)	(F,W)	-	-	-	-	-	+
Snow goose (Chen hyperborea)	(F,W)	-	-	-	+	+	+
Lesser scaup (Aythya affinis)	(F,W)	-	-	-	+	-	-
Marsh hawk (Circus cyaneus)	(F,M)	-	-	+	+	+	+
Harris hawk (Parabuteo unicinctus)	(F,M)	-	-	-	+	-	-

Notes: B = sitting on bay shore or intertidal waters; F = flying over the site; P = perching on the ground or vegetation; R = permanent resident; M = winter or summer migrant; W = winter resident
+ = an identification made on the study site or flying over the site
- = not seen during this month
* = nested on the study site.

Table 14 (CONTINUED)

Common Name (Scientific name)		Jul	Aug	Sept	Oct	Nov	Dec
Osprey (Pandion haliaetus)	(F,M)	-	-	-	-	+	-
Common egret (Casmerodius albus)	(F,W)	+	+	-	-	+	+
Cattle egret (Bubulcus ibis)	(P,R)	+	+	-	-	-	-
Snowy egret (Egretta thula)	(B,R)	+	-	+	-	+	-
Great blue heron (Ardea herodias)	(B,R)	+	+	+	+	+	+
Louisiana heron (Hydranassa tricolor)	(B,R)	+	+	+	-	+	-
Little blue heron (Florida caerulea)	(B,R)	+	-	-	-	-	-
Black-crowned night heron (Nycticorax nycticorax)	(F,R)	+	-	-	-	-	-
Yellow-crowned night heron (Nyctanassa violacea)	(F,R)	-	-	+	-	-	-
White-faced ibis (Plegadis chihi)	(F,M)	+	+	+	-	-	-
White ibis (Eudocimus albus)	(F,R)	-	-	+	-	-	-
Roseate spoonbill (Ajaia ajaja)	(F,M)	+	+	-	-	-	-
Virginia rail (Rallus limicola)	(P,W)	+	+	-	+	-	-
American avocet (Recurvirostra americana)	(B,M)	+	-	-	-	+	-
Black-necked stilt (Himantopus mexicanus)	(B,M)	+	-	-	-	-	-

Table 14 (CONTINUED)

Common Name (Scientific name)		Jul	Aug	Sept	Oct	Nov	Dec
Black-bellied plover (Squatarola squatarola)	(B,W)	+	+	+	+	+	+
Piping plover (Charadrius melodus)	(B,W)	-	+	+	-	+	-
Snowy plover (Charadrius alexandrinus)	(B,W)	-	-	+	+	+	+
Semipalmated plover (Charadrius semipalmatus)	(B,M)	-	+	-	-	-	-
Wilson's plover (Charadrius wilsonia)	(B,M)	+	+	+	+	-	-
Killdeer (Charadrius vociferus)	(B,R)	+	+	+	+	+	+
Long-billed curlew (Numenius americanus)	(F,M)	+	+	+	+	+	+
Spotted sandpiper (Actitis macularia)	(B,W)	-	+	-	-	-	-
Willet (Catoptrophorus semipalmatus)	(B,R)	+	+	+	+	+	+
Greater yellowlegs (Totanus melanoleucus)	(B,W)	-	-	-	-	-	+
Ruddy turnstone (Arenaria interpres)	(B,R)	+	+	-	-	+	+
Pectoral sandpiper (Erolia melanotos)	(B,M)	-	-	+	-	+	+
Dunlin (Erolia alpina)	(B,M)	-	-	+	+	+	-
Knot (Calidris canutus)	(B,M)	-	-	-	-	+	-
Sanderling (Crocethia alba)	(B,M)	-	+	+	+	+	+

Table 14 (CONTINUED)

Common Name (Scientific name)		Jul	Aug	Sept	Oct	Nov	Dec
White-rumped sandpiper (*Erolia fuscicollis*)	(F,M)	-	+	-	-	-	-
Least sandpiper (*Erolia minutilla*)	(B,M)	+	+	+	-	+	-
Semipalmated sandpiper (*Ereunetes pusillus*)	(B,M)	-	+	+	+	+	+
Herring gull (*Larus argentatus*)	(F,W)	+	-	+	+	+	+
Ring-billed gull (*Larus delawarensis*)	(F,R)	-	+	-	+	+	+
Laughing gull (*Larus atricilla*)	(B,R)	+	+	+	+	+	+
Least tern (*Sterna albifrons*)	(F,R)*	+	+	-	-	-	+
Common tern (*Sterna hirundo*)	(F,R)	+	+	+	+	+	+
Forster's tern (*Sterna forsteri*)	(B,M)	-	-	-	-	-	+
Gull-billed tern (*Gelochelidon nilotica*)	(B,R)	+	-	-	-	+	+
Royal tern (*Thalasseus maximus*)	(F,R)	-	-	+	+	+	+
Caspian tern (*Hydroprogne caspia*)	(B,R)	+	+	+	+	+	+
Black tern (*Childonias niger*)	(F,M)	+	+	+	-	-	-
Black skimmer (*Rynchops niger*)	(F,R)	+	+	+	-	-	-
Mourning dove (*Zenaida macroura*)	(P,R)	+	+	+	+	+	+

Table 14 (CONTINUED)

Common Name (Scientific name)		Jul	Aug	Sept	Oct	Nov	Dec
Yellow-billed cuckoo (*Coccyzus americanus*)	(P,M)	+	+	+	-	-	-
Common nighthawk (*Chordeiles minor*)	(P,M)	+	+	+	+	-	-
Ruby-throated hummingbird (*Archilochus colubris*)	(F,M)	-	+	-	-	-	-
Scissor-tailed flycatcher (*Muscivora forficata*)	(P,M)	+	+	+	+	-	-
Eastern kingbird (*Tyrannus tyrannus*)	(P,M)	+	+	+	-	-	-
Great crested flycatcher (*Myiarchus crinitus*)	(P,M)	-	+	-	-	-	-
Eastern phoebe (*Sayornis phoebe*)	(P,R)	-	+	-	-	-	-
Barn swallow (*Hirundo rustica*)	(F,M)	+	+	+	+	+	-
Rough-winged swallow (*Stelgidopteryx ruficollis*)	(F,R)	-	+	+	+	+	-
Purple martin (*Progne subis*)	(F,M)	+	-	-	-	-	-
Common crow (*Corvus brachyrhynchos*)	(F,R)	-	-	+	-	-	-
Short-billed marsh wren (*Cistothorus platensis*)	(P,W)	-	-	-	+	+	+
Mockingbird (*Mimus polyglottos*)	(P,R)	+	-	-	-	-	-
Brown thrasher (*Toxostoma rufum*)	(P,R)	-	-	+	-	-	-
Robin (*Turdus migratorius*)	(P,W)	-	-	+	-	-	-

Table 14 (CONTINUED)

Common Name (Scientific name)		Jul	Aug	Sept	Oct	Nov	Dec
Veery (Hylocichla fuscesens)	(P,M)	-	-	-	-	-	+
Blue-gray gnatcatcher (Polioptila caerulea)	(P,R)	-	-	+	+	-	-
Ruby-crowned kinglet (Regulus calendula)	(P,W)	-	-	+	-	-	-
Water pipit (Anthus spinoletta)	(B,W)	-	-	-	-	-	+
Sprague's pipit (Anthus spragueii)	(B,W)	-	-	-	-	-	+
Cedar waxwing (Bombycilla cedrorum)	(P,W)	-	-	+	-	-	-
Loggerhead shrike (Lanius ludovicianus)	(P,R)	-	-	+	+	+	+
White-eyed vireo (Vireo griseus)	(P,R)	-	-	-	-	-	+
Orange-crowned warbler (Vermivora celata)	(P,W)	-	-	-	+	-	-
Louisiana waterthrush (Seiurus motacilla)	(B,M)	-	-	+	-	-	-
Eastern meadowlark (Sturnella magna)	(P,R)	+	+	+	+	+	+
Red-winged blackbird (Agelaius phoeniceus)	(P,R)	+	+	+	-	+	+
Boat-tailed grackle (Cassidix mexicanus)	(P,R)	+	+	+	-	-	-
Common grackle (Quiscalus quiscula)	(P,R)	+	+	-	+	-	-
Brown-headed cowbird (Molothrus ater)	(P,R)	+	+	+	-	-	-

Table 14 (CONCLUDED)

Common Name (Scientific name)		Jul	Aug	Sept	Oct	Nov	Dec
Orchard oriole (Icterus spurius)	(P,M)	+	+	+	-	-	-
Baltimore oriole (Icterus galbula)	(P,M)	-	-	+	-	-	-
Blue grosbeak (Guiraca caerulea)	(P,M)	-	-	+	-	-	-
Savannah sparrow (Passerculus sandwichensis)	(P,W)	-	-	-	-	+	+
Grasshopper sparrow (Ammodramus savannarum)	(P,W)	-	-	-	-	-	+
Le Conte's sparrow (Passerherbulus caudacutus)	(P,W)	-	-	+	-	-	+
Seaside sparrow (Ammospiza maritima)	(P,R)	-	-	+	-	-	+
Vesper sparrow (Pooecetes gramineus)	(P,W)	-	-	-	-	+	+
Chipping sparrow (Spizella passerina)	(P,W)	-	-	-	+	-	-
Field sparrow (Spizella pusilla)	(P,W)	-	-	-	-	-	+
Swamp sparrow (Melospiza georgiana)	(P,W)	-	-	-	+	-	+
Song sparrow (Melospiza melodia)	(P,W)	-	-	-	+	+	+
TOTALS		41	43	50	37	43	45

Table 15

Mammals Captured or Seen on the Bolivar Peninsula Study Site

Species	Common Name	Abundance*
Didelphis marsupialis	opossum	r
Blarina brevicauda	short-tailed shrew	r
Procyon lotor	raccoon	vc
Spilogale putorius	spotted skunk	r
Myocastor coypus	nutria	r
Mus musculus	house mouse	c
Sigmodon hispidus	cotton rat	vc
Sylvilagus aquaticus	swamp rabbit	c
Sylvilagus floridanus	cottontail rabbit	r
Dasypus novemcinctus	armadillo	vc
Capra hircus	goat	vc
Bos indicus	cow	c
Ovis aries	sheep	c

*r = rare, seen only once; c = common, seen occasionally; vc = very common, seen or captured every visit.

Table 16

Population Estimates of Small Mammals on the Study Site, 1975

Species	Population per Hectare Oct.	Nov.	Dec.
Sigmodon hispidus	25.3	35.3	29.1
Mus musculus	*	1.6	10.2

* Population too low to estimate

(juveniles) do not enter traps as readily as socially dominant (adult) individuals.

62. Most of the rats were collected from the Spartina patens and Andropogon communities. These apparently provided adequate protection in the form of cover.

63. The house mouse was not trapped in sufficient numbers to estimate its population until November. In December, trapped animals were 73.3% male and 26.7% female.

64. The Monarda community supported the largest house mouse population, with Spartina second. Sesbania-mixed grass supported the lowest. Vegetative community use by the house mouse was thus opposite that by the cotton rat.

65. The number of other mammals captured or seen was small and no population estimates were made. Eighteen raccoons were collected from the study site and moved to the mainland to reduce interference with the small mammal survey. Rabbits were abundant, estimated to be at least one per hectare, based on periodic sighting and scats. Nutria were seen in the marsh, and skunks and armadillo in all vegetation types.

66. Normal mammal species numbers on the mainland adjacent to Galveston Bay are 15-16. High numbers, such as found in a refuge, would be 22. This study site's ten is comparatively low.

67. Herptiles. The diversity of reptiles and amphibians on the study site was low with only 11 species sighted (Table 17). Eight of these feed on insects and two (cottonmouth and kingsnake) feed on mammals and birds. The salt marsh snake also feeds on crabs and crayfish. Population estimates of reptiles and amphibians were not made due to the low numbers observed.

68. Macroinvertebrates. The macroinvertebrate fauna was sampled from the edge of Galveston Bay to the GIWW. Population estimates of only a few forms were made since the techniques used did not allow for collection of quantitative data for all groups. Other species were reported as observed (Table 18). Species represented are considered similar to those in other sections of Galveston Bay.

Table 17

Amphibians and Reptiles Observed on the Bolivar Peninsula Study Site

Species	Common name	Number of Observations
Bufo valliceps	gulf coast toad	7
Gastrophryne carolinensis	narrow-mouth frog	1
Eumeces sp.	skink	1
Cnemidophorus sexlineatus	six-lined racerunner	5
Phrynosoma cornutum	Texas horned lizard	3
Ophisaurus attenuatus	glass lizard	2
Terrapene ornata ornata	ornate box turtle	4
Thamnophis sirtalis sirtalis	eastern garter snake	1
Natrix fasciata clarki	salt marsh snake	5
Agkistrodon piscivorus	cottonmouth	2
Lampropeltis getulus holbrooki	speckled kingsnake	1

AD-A063 780 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS F/G 13/3
HABITAT DEVELOPMENT FIELD INVESTIGATIONS, BOLIVAR PENINSULA MAR--ETC(U)
AUG 78 H H ALLEN, E J CLAIRAIN, R J DIAZ

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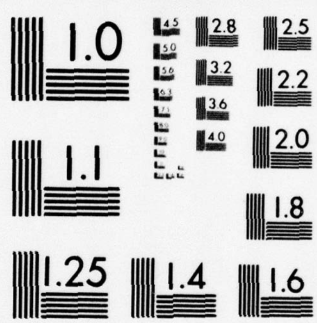
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1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6
6.3

Table 18

Macroinvertebrate Fauna of the Bolivar Peninsula Study Site

ORDER	FAMILY SPECIES	COMMON NAME	POPULATION (M^2)
CAPITELLIDA	CAPITELLIDAE	polychaeta	
	Mediomastus californiensis		18.0
PHYLLODOCIDA	EUNICIDAE	polychaeta	
	Diopatra cuprea		9.0
	2 species	unidentified	6.0
	Succinea ovalis	land snail	2.0
	Succinea sp.	land snail	4.0
	Mesomphyx sp.	land snail	0.5
	Zonitoides sp.	land snail	0.1
LABIDOGNATHA	DYSDERIDAE	dysdersids spiders	0.5
	LOXOSCELIDAE	brown spiders	1.0
	THERIDIIDAE	cobweb spiders	0.1
	LINYPHIIDAE	dwarf spiders	2.0
	ARANEIDAE	orb-weavers	1.0
	TETRAGNATHIDAE		0.1
	LYCOSIDAE	wolf spiders	0.2
	THOMISIDAE	crab spiders	0.2
	SALTIDIDAE	jumping spiders	0.2
SCORPIONES	BUTHIDAE	centruroides	0.1
ACARINA	IXODIDAE		
	Amblyomma americanum	tick	4.0
ISOPODA	ARMADILLIDIIDAE	pill bug	0.2
DECAPODA	PAGURIDAE		
	Pagurus sp.	hermit crab	-
	OCYPODIDAE		
	Ocypode quadrata	ghost crab	-
	Uca pugnax	mud fiddler	21.0
ODONATA	AESHNIDAE		
	Aeshna sp.	darners	-
	LIBELLULIDAE		
	Sympetrum sp.	skimmers	0.1
	COENAGRIOMIDAE		
	Enallagma	damselflies	0.1
ORTHOPTERA	ACRIDIDAE	short-horned grasshopper	6.0
	TETRIGIDAE	pygmy grasshopper	-
	TETTIGONIIDAE	long-horned grass-hopper	-
	GRYLLIDAE	ground cricket	2.0

Table 18 (CONTINUED)

ORDER	FAMILY SPECIES	COMMON NAME	POPULATION (M^2)
	PHASMATIDAE	walking stick	0.1
	MANTIDAE	mantid	0.1
	BLATTIDAE	cockroach	
	BLATTELLIDAE	woodroach	
DERMAPTERA	LABIDURIDAE		
	Labidura sp.	earwig	1.0
HEMIPTERA	BELOSTOMATIDAE	water bug	-
	PENTATOMIDAE	stink bug	1.0
	REDUVIIDAE	assassin bug	-
	LYGAEIDAE	seed bug	-
	LARGIDAE	largid bug	-
	CYDNIDAE	burrower bug	-
	MIRIDAE	plant bug	2.0
HOMOPTERA	CICADIDAE	cicadas	1.0
	CICADELLIDAE	leafhoppers	3.0
	FULGOROIDAE	planthoppers	-
	APHIDIDAE	aphids	-
	DIASPIDIDAE	scales	-
COLEOPTERA	CICINDELIDAE	tiger beetles	6.0
	CARABIDAE	ground beetles	2.0
	STAPHYLINIDAE	rove beetles	1.0
	LAMPHYRIDAE	fireflies	1.0
	DERMESTIDAE	dermistids	-
	MELYRIDAE	flower beetles	-
	CLERIDAE	checkered beetles	-
	ELATERIDAE	click beetles	-
	BUPRESTIDAE	wood-boring beetles	-
	DASCILLIDAE	soft-bodied plant	-
	CUCUJIDAE	flat bark beetles	1.0
	COCCINELLIDAE	ladybird beetles	2.0
	CEPHALOIDAE	false longhorn beetles	-
	MELOIDAE	blister beetles	1.0
	TENEBRIONIDAE	darkling beetles	2.0
	ANOBIIDAE	anobids	-
	LUCANIDAE	stag beetles	-
	SCARABAEIDAE	scarab beetles	3.0
	CERAMBYCIDAE	long-horned beetles	2.0
	CHRYSOMELIDAE	leaf beetles	1.0
	CURCULIONIDAE	snout beetles	1.0
	RHYNCHOPHORIDAE	grain weevils	1.0
NEUROPTERA	CORYDALIDAE	dobsonflies	-
	CHRYSOPIDAE	lacewings	-
	MYRMELEONTIDAE	antlions	-

Table 18 (CONCLUDED)

ORDER	FAMILY SPECIES	COMMON NAME	POPULATION (M^2)
TRICHOPTERA	PHRYGANEIDAE	large caddisflies	-
	LIMNEPHILIDAE	northern caddisflies	-
LEPIDOPTERA	PAPILIONIDAE	swallowtails	-
	PIERIDAE	sulphurs	-
	DANAIDAE	milkweed	-
	HELICONIIDAE	heliconiana	-
	SPHINGIDAE	sphinx	-
	ARCTIIDAE	tiger moth	-
	LASIOCAMPIDAE	tent caterpillars	-
	GEOMETRIDAE	geometers	-
	GELECHIIDAE	grain moths	-
	PSYCHIDAE	bagworm moths	-
DIPTERA	TIPULIDAE	crane flies	-
	PSYCHODIDAE	sand flies	-
	CHAOBORIDAE	plantom midges	-
	CULICIDAE	mosquitoes	-
	CERATOPOGONIDAE	biting midges	-
	TABANIDAE	horse flies	-
	ASILIDAE	robber flies	1.0
	SCIOMYIDAE	marsh flies	1.0
	MUSCIDAE	house flies	-
HYMENOPTERA	ICHNEUMONIDAE	ichneumons	-
	TIPHIIDAE	tiphids	-
	MUTILLIDAE	velvet ants	-
	FORMICIDAE	ants	100+
	APIDAE	bees	-

69. The most common invertebrates were grasshoppers and land snails. The mud fiddler crab was very numerous (Table 18) in the restricted habitat occupied (i.e. mud areas around freshwater marshes). Ghost crabs were numerous along the bay shore as were tiger beetles in the summer months.

70. Polychaeta were numerous ($181/m^2$) in the beach soil within the top six inches of the surface. Other larvae (Insecta) were also found in this area and numbered as high as $60/m^2$ in the summer months.

PART VI: SEDIMENT CHEMISTRY

71. Baseline information regarding the soils and sediments presently located in the proposed study site was collected in this phase of the study. The information collected will determine the chemical and physical characteristics of the sediments prior to proposed dredging and disposal operations on the site.

72. Sediment and soil samples were analyzed to determine those agronomic properties that were considered important to the establishment of marsh vegetation. Potential pollution and toxic characteristics of the materials were also examined.

Methods

73. Nine sediment cores were taken along three of the random transect lines in the study site. Sediment cores were taken with a stainless steel coring device fitted with a PVC liner. The PVC liners were cleaned with nitric acid and thoroughly rinsed with distilled water prior to use to prevent contamination of the sediment sample. Also, each liner was precut to the proper length, then taped prior to insertion into the coring device. Each core was about 110 cm in length.

74. Immediately after the core was taken, the plastic liner was extruded from the core barrel into a large glove bag that had been purged with nitrogen (N_2) gas. The core sections were separated (10-cm top section, and successive 25-cm lower sections) and each end of the section capped while it was in the glove bag. Core sections were then transported to the laboratory for further analyses.

75. Each core section was extruded from the PVC liner in the laboratory under a nitrogen atmosphere. The Eh and pH measurements were made in the glove bag to prevent oxidation of the core. A small portion of each core section was sealed under a nitrogen atmosphere in a plastic vial to be used for sulfide analysis.

76. The cores were removed from the glove bag. Half of each core section was used for soil classification, and the other half was stored at 4^{o} C for subsequent analyses.

77. Interstitial water samples were taken in the field from the sediments in situ. PVC pipes, 6 inches in diameter and 4 feet long, were driven into the ground. The sediment was removed from the inside of the PVC pipe. Plastic gas dispersion tubes were fitted through holes drilled

in the wall of the PVC pipe so that the porous ends of the dispersion tubes were sticking into the sediment. Plastic vials were attached to the dispersion tubes, and a partial vacuum was applied to pull the interstitial water from the sediments (Figure 3). When full, the plastic vials were removed, and the interstitial pore water collected was acidified with hydrochloric acid (HCl). The plastic vials were then sealed and stored at 4°C prior to interstitial water analysis.

Total core analysis

78. Eh and pH. Measurements of these two parameters were made in an oxygen-free atmosphere. The Eh measurements were made with a shiny platinum electrode and a calomel half-cell as reference; pH measurements were made with a standard glass electrode and calomel half-cell. The electrodes were placed in the center of each core section prior to Eh and pH measurement.

79. Total sulfide (Beaton and Burns 1968). A sediment sample was placed in a Kjeldahl flask and mixed with distilled water. The sample was boiled under a nitrogen atmosphere while HCl was being added. The hydrogen sulfide (H_2S) evolved was trapped in a cadmium-zinc acetate solution. Excess iodine solution was added along with HCl. The excess iodine was back-titrated with standard sodium thiosulphate solution. Results are reported in units of milligrams per kilogram of wet sediment.

80. Particle-size distribution (Day 1965). Percent sand (> 53μ), silt (2-53μ), and clay (< 2μ) were determined for each section by the sieve-pipette method.

81. Total organic matter (Allison 1965). Readily oxidizable organic matter in the sediment sample was oxidized by dichromate ion ($Cr_2O_7^{-2}$) in the presence of sulfuric acid (H_2SO_4). The excess $Cr_2O_7^{-2}$ was determined by titration with a standard ferrous sulphate ($FeSO_4$) solution. The quantity of organic matter oxidized was calculated from the amount of $Cr_2O_7^{-2}$ reduced. All results are reported as percent organic matter in the dry sediment.

82. Total organic nitrogen (Bremner 1965a). A sediment sample was placed into a 100-ml micro-Kjeldahl flask. A potassium sulfate (K_2SO_4) catalyst mixture was added to the flask along with concentrated sulfuric acid (H_2SO_4). The flask was boiled until the sediment sample was properly

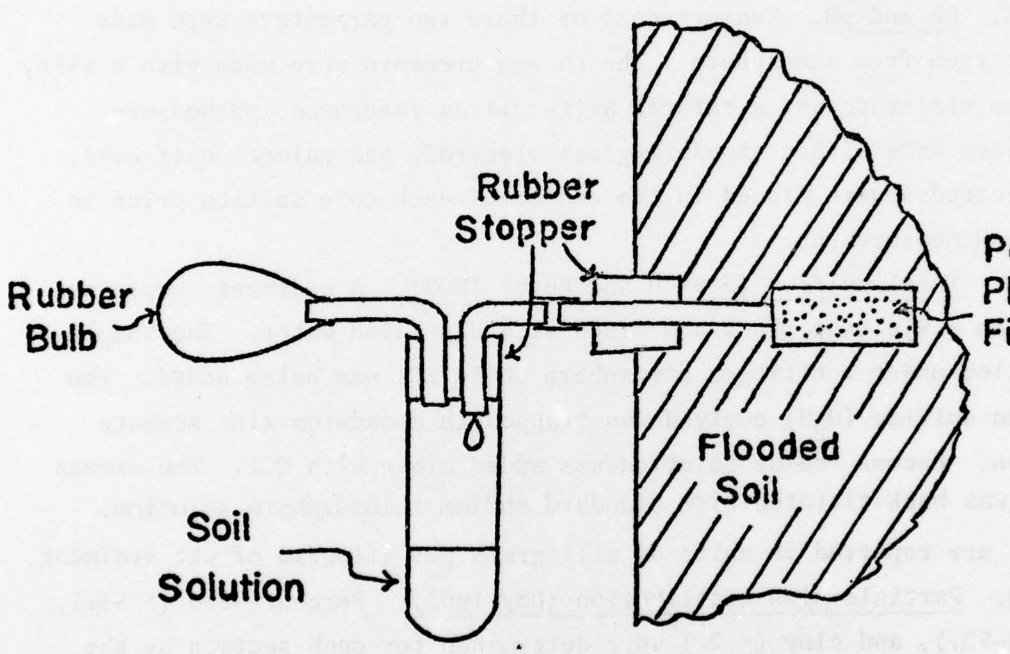

Figure 3. Method used for sampling of interstitial pore water in the field

digested. The total organic nitrogen present was determined by steam distillation of ammonia utilizing a boric acid (H_3BO_3) indicator solution. Data will be reported as milligrams of nitrogen per kilogram of dry sediment.

83. Ammonium (Bremner 1965b). Exchangeable ammonium was extracted with a 2-N potassium chloride (KCl) solution and the ammonium-N(NH_4^+-N) determined by steam distillation. Data will be reported as milligrams of nitrogen per kilogram of dry sediment.

84. Cation exchange capacity (Keeney and Bremner 1969). The cation exchange capacity was determined by treating the sediment sample with 1-N ammonium acetate (NH_4OA) (pH 7.0), after which NH_4OA was removed by leaching with an ammonium nitrate (NH_4NO_3) solution. The treated sample was analyzed for NH_4^+-N and NO_3^--N by steam distillation methods. Data will be reported as milliequivalents per 100 g of sediment.

85. Extractable orthophosphate (Watanabe and Olsen 1965). Orthophosphate was extracted from the sediment sample with distilled water (H_2O). Ammonium molybdate-antimony potassium tartrate and ascorbic acid reagents were added. The extractable orthophosphate was then determined by the intensity of the blue color produced. The results will be reported as milligrams of phosphorus per liter of solution.

86. Metals (atomic absorption methods) (U.S. Environmental Protection Agency (EPA) 1974). A sediment sample was completely dissolved using hydrofluoric acid (HF), nitric acid (HNO_3), and perchloric acid ($HClO_4$). The metals released were determined by flame and flameless atomic absorption methods. The results will be reported as micrograms of metal per gram of sediment.

Interstitial water analysis

87. Nitrate-N (U.S. Environmental Protection Agency (EPA) 1974). Nitrate-N was reduced to nitrite with cadmium-copper (Cd-Cu) catalyst. The nitrites (those originally present plus reduced nitrates) were reacted with sulfanilamide to form a diazo compound which was then coupled with N-(1 napthyl -ethylenediamine hydrochloride) at pH 2.0 to form the azo dye. The azo dye intensity, which was proportional to the nitrate concentration, was then measured. Separate rather than combined nitrate-nitrite values were readily obtainable by carrying out the procedure first with and then without the initial Cd-Cu reduction step.

Data will be reported as milligrams per liter of nitrate-N.

88. Nitrite-N (U.S. Environmental Protection Agency (EPA) 1974). A diazonium compound formed by diazotization of sulfanilamide by nitrite in water under acid conditions was coupled with N-(1-naphthyl)-ethylenediamine to produce a reddish-purple color, the intensity of which was then measured. Data will be reported as milligrams per litre of nitrite-N.

89. Ammonium-N (U.S. Environmental Protection Agency (EPA) 1974). This distillation method can be used to measure ammonium-N exclusive of total Kjeldahl nitrogen in surface waters, domestic and industrial wastes, and saline waters.

90. The sample was buffered at a pH of 9.5 with a borate buffer to decrease hydrolysis of cyanates and organic nitrogen compounds. It was then distilled into a solution of boric acid. The ammonia in the distillate was determined titrimetrically with standard H_2SO_4 and a mixed indicator. The results will be reported as milligrams per litre of ammonium-N.

91. Total Kjeldahl nitrogen (U.S. Environmental Protection Agency (EPA) 1974). The sample was heated in the presence of concentrated sulfuric acid (H_2SO_4), potassium sulfate (K_2SO_4), and magnesium sulfate ($MgSO_4$), and then evaporated until sulfur trioxide (SO_3) fumes were obtained and the solution became colorless or pale yellow. The residue was cooled, diluted, and made alkaline with a hydroxidithiosulfate solution. The ammonium was determined titrimetrically after distillation.

92. Total phosphorus and orthophosphate (U.S. Environmental Protection Agency (EPA) 1974). The method is based on reactions that are specific for the orthophosphate ion. The methods are applicable to the range of 0.01-0.5 milligrams per liter of phosphorus.

93. Ammonium molybdate and potassium antimony tartrate were reacted with dilute solutions of phosphorus to form an antimony-phospho-molybdate complex. This complex becomes an intense blue when ascorbic acid is added. The color, which is proportional to the orthophosphate concentration, was then measured. The data will be reported as milligrams per litre.

94. Dissolved organic carbon (U.S. Environmental Protection Agency (EPA) 1974). Five ml of filtered interstitial water, 0.25 ml of 6 percent

phosphoric acid (H_3PO_4), and 0.2 g of potassium persulfate ($K_2S_2O_8$) were placed in a 10-ml glass ampule. Hot oxygen (O_2) gas was bubbled through the sample, and after 6 minutes the ampule was sealed with a flame. The sealed ampules were placed overnight in an oven at 110^{o} centigrade (C) to convert the organic carbon to carbon dioxide (CO_2). The evolved CO_2 was measured by an infrared detector. The results will be reported as milligrams of carbon per litre.

95. Metals (atomic absorption methods) (U.S. Environmental Protection Agency (EPA) 1974). Metals in solution were determined by atomic absorption spectroscopy. A Perkin-Elmer model 403 atomic absorption spectrophotometer was used. The results will be reported as micrograms of metal per millilitre of solution.

Results

96. Nine separate locations were chosen from which core samples to a depth of 107 cm would be taken (Figure 4). The locations were chosen to coincide with and transect the major vegetation types on the Bolivar site. Three core samples were taken from an upland location where oxidized conditions would be expected to exist throughout the profile. Intermediate locations were chosen to include sites where the profile was generally oxidized in the surface but reduced in the lower profile and where a free water table might exist. The last three locations were in the intertidal area and were saturated with water at all times.

97. Initially, six profiles (cores 1-6) were sampled and transported to the laboratory. Attempts were made to extract sufficient interstitial water to perform chemical analysis. However, due to the low total water content of the sediments and low compressibility, it was not possible to extract enough water by centrifugation or by compression for analysis. It was then decided to extract interstitial water in the field. The remaining three cores (7-9) and the interstitial water samples were taken about a week later. Due to the large volume of interstitial water needed for all chemical analysis, an additional set of water samples were pulled about a week after the first set of interstitial water samples were taken. Because of the problems involved in obtaining interstitial water samples, some care must be taken when comparing interstitial water analyses to corresponding core analyses. Interstitial water samples and

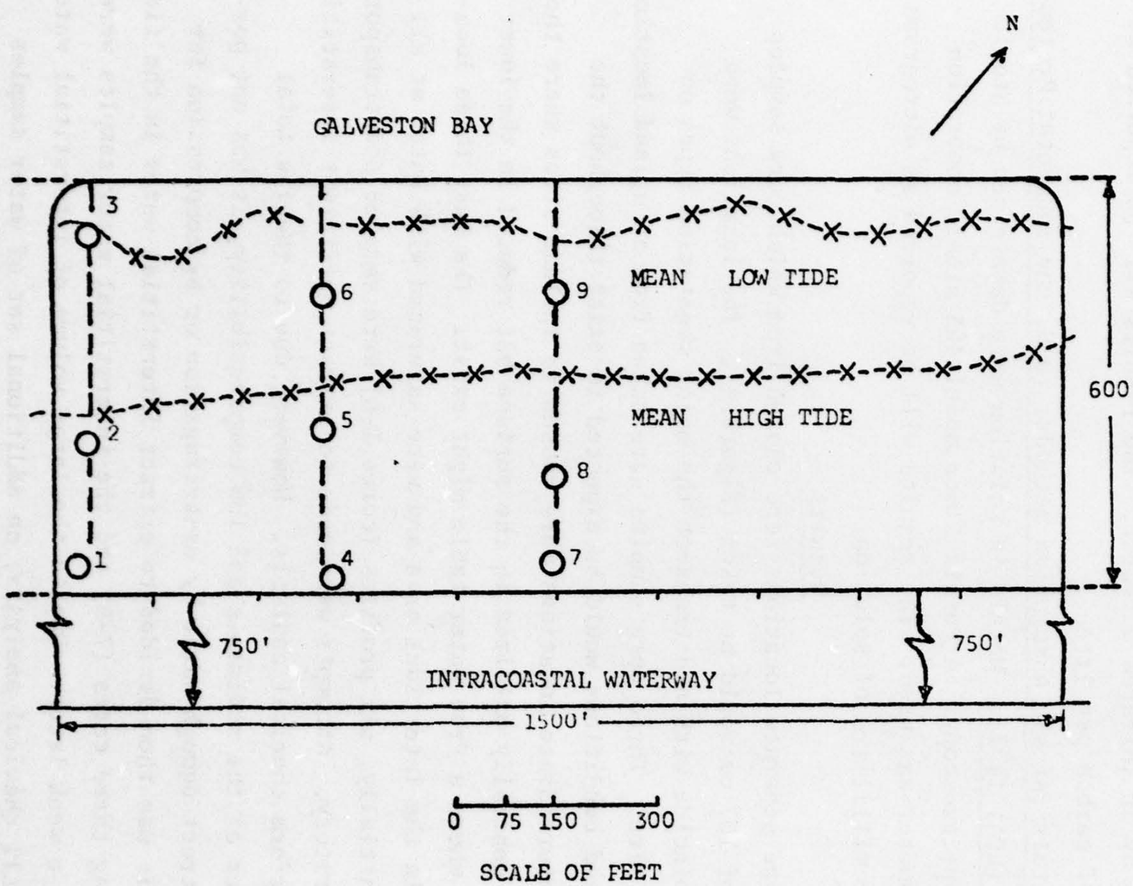

Figure 4. Bolivar Peninsula experimental site with locations of nine core samples taken for chemical and physical analysis

core samples were pulled at different times and, in some cases, from slightly different locations.

98. Sediment samples taken to a depth of 107 cm were all sandy in texture. There was some variation with depth in terms of texture, color, and organic matter. There were also some pockets of shells, silt, and clay. Complete core descriptions are given in Appendix B'.

Upland sites

99. Cores were taken near the baseline and numbered as cores 1, 4, and 7. Data for core 1 are given in Tables 19 and 20, core 4 in Tables 21 and 22, and core 7 in Tables 23 and 24. For these sites there was inadequate soil moisture for interstitial water samples.

100. Color, as determined from the Munsel color charts, was consistent for the three sites. The normal reading was 10 YR 5/2 throughout most of each profile.

101. Moisture content of the cores varied, primarily because of the time of sampling. Cores 1 and 4 were taken prior to and core 7 was taken following a rainy period. The primary difference was the high moisture content throughout the profile of core 7. Core 7 also had a lower Eh value in the lower section of the profile.

102. Textural analysis of the cores shows that the profiles are sand to a depth of 107 cm. Sand content of the sediments ranged from 88.4 to 98.97 percent. Clay content ranged from 0 to 5.00 percent. However, in most profiles the clay content was less than 2 percent.

103. Eh values generally reflected the moisture content of the profiles. The lower the moisture content, the higher the redox potential of the core section. pH values were all above neutrality. Individual horizon values ranged from a low of 7.10 to a high of 8.40.

104. Total organic nitrogen and organic carbon were closely related. As the organic carbon increased from 0.04 to 0.36 percent, the organic nitrogen also increased from 21 to 202 mg/kg.

105. Exchangeable ammonium (NH_4^+) was generally low (< 0.30 mg/kg). Core 7, which was taken after a tropical storm had moved through the area, had consistently high amounts of exchangeable NH_4^+. Water-extractable orthophosphate was relatively high with most values over 0.10 mg/kg. Values ranged from a low of 0.042 to 0.741 mg/kg.

Table 19

Chemical and Physical Analyses of Sediments Taken at Various Depths at Location 1, an Upland Location from Bolivar Peninsula Study Site

Core Section (cm)	Color	Moisture Content (%)	Particle-Size Distribution (%) Sand	Silt	Clay	Eh (mv)	pH	Total Organic Matter (%)	Total Organic Nitrogen (mg/kg)	Ammonium (mg/kg)	Extractable Ortho-phosphate (mg/kg)
0-10	10 YR 5/2	4.80	98.97	1.25	0.00	+492	7.10	0.12	52.0	<0.30	0.333
10-35	10 YR 6/2	4.50	96.97	1.25	1.25	+471	7.40	0.13	29.9	<0.30	0.208
35-60	10 YR 5/2	2.47	96.00	2.50	1.25	+491	7.25	0.16	43.8	<0.30	0.167
60-85	10 YR 5/2	13.20	88.40	6.25	5.00	+456	8.40	0.18	70.5	<0.30	0.150
85-107	10 YR 4/1	11.20	95.99	2.50	1.25	+461	8.25	0.28	95.1	0.36	0.175

Table 20

Chemical Analyses of Sediments Taken at Various Depths at Location 1,

an Upland Location from Bolivar Peninsula Study Site

Core Section (cm)	Calcium (μg/g)	Potassium (μg/g)	Sodium (μg/g)	Magnesium (μg/g)	Iron (μg/g)	Manganese (μg/g)	Zinc (μg/g)	Copper (μg/g)	Lead (μg/g)	Cadmium (μg/g)	Mercury (μg/g)	Sulfide (μg/g)	Cation Exchange Capacity (meq/100g)
0-10	8,290	2,860	3,010	710	3,560	122	12.6	10.0	8.6	0.70	0.05	1.00	0.95
10-35	9,660	4,980	3,120	810	4,030	135	14.7	15.9	11.0	0.70	0.05	0.62	1.10
35-60	8,390	4,720	3,570	990	4,750	111	16.5	13.1	10.2	0.70	0.08	<0.58	1.51
60-85	7,360	3,360	4,480	1,570	6,410	164	21.4	21.4	13.3	0.82	0.06	<0.58	3.40
85-107	37,410	5,700	3,150	1,250	5,200	276	16.8	11.7	12.0	1.36	0.05	<0.58	2.46

Table 21

Chemical and Physical Analyses of Sediments Taken at Various Depths at Location 4, an Upland Location from Bolivar Peninsula Study Site

Core Section (cm)	Color	Moisture Content (%)	Particle-Size Distribution (%) Sand	Silt	Clay	Eh (mv)	pH	Total Organic Matter (%)	Total Organic Nitrogen (mg/kg)	Ammonium (mg/kg)	Extractable Ortho-phosphate (mg/kg)
0-10	10 YR 5/2	6.5	96.15	2.50	1.25	+476	7.80	0.36	202.6	<0.30	0.042
10-35	10 YR 5/2	9.7	97.55	1.25	1.25	+486	8.05	0.06	43.1	<0.30	0.066
35-60	10 YR 5/1	17.2	96.72	2.50	1.25	+331	7.90	0.12	86.2	<0.30	0.233
60-85	10 YR 5/2	18.4	98.29	1.25	0.00	+286	8.00	0.09	48.4	<0.30	0.233
85-107	10 YR 5/2 & 10 YR 4/3	19.0	97.60	1.25	0.00	+136	7.90	0.04	25.3	<0.30	0.292

Table 22

Chemical Analyses of Sediments Taken at Various Depths at Location 4, an Upland Location from Bolivar Peninsula Study Site

Core Section (cm)	Calcium (μg/g)	Potassium (μg/g)	Sodium (μg/g)	Magnesium (μg/g)	Iron (μg/g)	Manganese (μg/g)	Zinc (μg/g)	Copper (μg/g)	Lead (μg/g)	Cadmium (μg/g)	Mercury (μg/g)	Sulfide (μg/g)	Cation Exchange Capacity (meq/100g)
0-10	10,190	5,590	2,920	720	3,790	120	13.3	9.8	8.9	0.70	0.04	1.26	0.41
10-35	3,210	3,490	1,680	390	2,070	61	8.6	22.7	3.9	0.41	0.05	<0.58	0.77
35-60	5,540	7,080	3,680	920	4,440	75	19.5	27.2	11.7	0.76	0.02	<0.67	0.25
60-85	5,970	3,870	2,990	740	3,640	85	13.6	13.7	9.0	0.70	0.04	<0.58	0.20
85-107	6,700	7,470	3,490	830	4,480	115	15.2	12.9	9.8	0.76	0.02	<0.58	0.08

Table 23

Chemical and Physical Analyses of Sediments Taken at Various Depths at Location 7, an Upland Location from Bolivar Peninsula Study Site

Core Section (cm)	Color	Moisture Content (%)	Particle-Size Distribution (%)			Eh (mv)	pH	Total Organic Matter (%)	Total Organic Nitrogen (mg/kg)	Ammonium (mg/kg)	Extractable Ortho-phosphate (mg/kg)
			Sand	Silt	Clay						
0-10	10 YR 5/2	14.7	95.77	2.50	2.50	+406	7.40	0.10	47.0	1.42	0.092
10-35	10 YR 5/2	18.7	98.29	0.00	1.25	+396	7.40	0.19	66.2	0.36	0.125
35-60	10 YR 5/2	17.7	99.46	0.00	1.25	+391	7.35	0.10	21.0	1.78	0.100
60-85	10 YR 5/2	19.7	96.27	3.75	0.00	+141	7.40	0.12	113.6	1.07	0.416
85-107	10 YR 5/2	19.5	94.99	1.25	1.25	-34	7.35	0.16	94.0	1.42	0.741

Table 24

Chemical Analyses of Sediments Taken at Various Depths at Location 7, an Upland Location from Bolivar Peninsula Study Site

Core Section (cm)	Calcium (μg/g)	Potassium (μg/g)	Sodium (μg/g)	Magnesium (μg/g)	Iron (μg/g)	Manganese (μg/g)	Zinc (μg/g)	Copper (μg/g)	Lead (μg/g)	Cadmium (μg/g)	Mercury (μg/g)	Sulfide (μg/g)	Cation Exchange Capacity (meq/100g)
0-10	7,010	4,980	2,990	650	3,180	102	15.4	43.6	19.2	0.70	0.05	<0.58	0.98
10-35	7,780	3,730	2,990	730	3,490	120	14.9	16.5	10.2	0.70	0.02	<0.58	1.17
35-60	6,680	4,720	2,860	610	3,060	100	13.8	16.0	10.2	0.68	0.05	<0.58	0.99
60-85	6,530	7,840	3,920	1,120	5,190	135	17.8	16.1	11.3	0.76	0.04	<0.58	1.72
85-107	11,280	5,880	4,410	1,790	6,080	152	20.8	14.3	11.5	1.02	0.06	<0.58	2.00

106. Cation exchange capacity for the three upland locations was low and ranged from 0.08 to 3.40 meq/100 g soil. There was no trend in cation exchange capacity down the length of the core.

107. Sulfide content of the core sections was low and appeared to decrease slightly with depth in the profile. Sulfide values range from less than 0.58 to 1.26 μg/g.

108. Fertility analysis on the top section of each core is given in Table 25. Exchangeable calcium was very high and exceeded levels of 6000 #Ca/A. Exchangeable magnesium ranged from medium to high with values averaging around 220 #Mg/A. Extractable phosphorus (approximately 40 #P_2O_5/A) and exchangeable potassium (approximately 120 #K_2O/A) are in the low to medium range. No salinity hazard appeared to exist in the upper profile of the upland area when these samples were collected. Concentrations of available zinc, iron, and manganese ranged from medium to high.

109. Total analysis for eleven different metals on each core section showed no relative trends (Tables 20, 21 and 22). Calcium values fluctuated somewhat but these were probably due to the amount of shell material found in the soil samples. Higher calcium values were usually accompanied by increases in potassium, iron, magnesium, and manganese. Lead values ranged from 3.9 to 19.2 μg/g. Cadmium values usually averaged less than 1 μg/g down the cores. Mercury values ranged from 0.02 to 0.08 μg/g throughout the cores.

Intermediate sites

110. Sediment core and interstitial water analyses are given for sample cores taken from intermediate positions in the study site in Tables 26-31. Color, moisture content, texture, and pH at these three sites were similar to those for the upland sites.

111. Eh potentials for these locations were different from those of the upland locations. Generally the potentials were positive in the upper portion of the horizon and decreased with depth as the result of saturated conditions at the lower depths. In fact, moisture content was high enough that interstitial water samples could be collected from the upper horizons of cores 5 and 8 and from depths below 35 cm for core 2.

112. With the exception of core 5, organic matter percentage was low (< 0.09 percent). These low values were also apparent in the cor-

Table 25

Fertility Analysis of Surface Samples from Bolivar Peninsula as Determined by Standard Methods

Used by the Texas Agricultural Extension Service Soil Testing Laboratory

Sample Location	Soil pH	Calcium (lbs/A* level+)		Magnesium (lbs/A level)		Phosphorus (lbs/A level)		Potassium (lbs/A level)		Sodium (lbs/A)	Salinity hazard	Zinc ppm level		Iron ppm level		Manganese ppm level	
								Upland Sites									
1	8.4	> 6000	VH	210	M	44	M	140	L	--	none	0.36	M	4.4	M	3.7	H
4	8.4	> 6000	VH	250	H	33	L	140	L	--	none	0.54	H	8.8	H	3.7	H
7	7.9	> 6000	VH	210	M	44	M	90	VL	--	none	0.90	H	4.8	MH	3.4	H
								Intermediate Sites									
2	8.0	> 6000	VH	465	H	37	L	100	VL	250	slight	0.32	M	5.6	H	5.0	H
5	8.4	> 6000	VH	395	H	33	L	150	L	--	none	0.56	H	8.0	H	3.0	H
8	8.6	> 6000	VH	330	H	20	VL	100	VL	--	none	0.46	H	5.0	MH	4.7	H
								Lowland Sites									
3	8.2	> 6000	VH	> 500	H	37	L	320	H	3180	medium	0.52	H	9.8	H	4.7	H
6	7.3	> 6000	VH	> 500	H	20	VL	350	H	2530	medium	0.62	H	16.0	H	5.2	H
9	8.1	> 6000	VH	> 500	H	33	L	410	H	2420	medium	0.74	H	12.4	H	3.9	H

*pounds per acre 6 inches

+VL = very low
L = low
M = medium
MH = medium high
H = high
VH = very high

Table 26

<u>Chemical and Physical Analyses of Sediments and Chemical Analysis of Interstitial Water Taken at Various Depths at Location 2, an Intermediate Location from the Bolivar Peninsula Study Site</u>

Sediment Analysis

Core Section (cm)	Color	Moisture Content (%)	Particle-Size Distribution (%) Sand	Silt	Clay	Eh (mv)	pH	Total Organic Matter (%)	Total Organic Nitrogen (mg/kg)	Ammonium (mg/kg)	Extractable Ortho-phosphate (mg/kg)
0-10	10 YR 5/2	7.00	99.10	0.00	1.25	+451	7.10	0.07	16.0	0.71	0.191
10-35	10 YR 5/2	11.70	95.49	1.25	1.25	+426	7.80	0.07	23.9	<0.30	0.300
35-60	10 YR 4/1	16.90	97.02	1.25	1.25	+456	8.10	0.09	19.6	<0.30	0.525
60-85	10 YR 4/1	19.70	90.96	7.50	1.25	- 44	7.70	0.08	32.4	<0.30	0.750
85-107	10 YR 4/1	19.10	96.61	1.25	1.25	- 84	8.50	0.05	16.0	<0.30	0.333

Interstitial Water Analysis

Core Section (cm)	Ammonium-N (mg/ℓ)	Nitrate-N (mg/ℓ)	Nitrite-N (mg/ℓ)	Total Inorganic Nitrogen (mg/ℓ)	Total Phosphorus (mg/ℓ)	Ortho-phosphate (mg/ℓ)	Dissolved Organic Carbon (mg C/ℓ)
35-60	0.00	2.95	0.018	2.96	0.396	0.225	3.50
60-80	0.12	1.16	<0.005	1.28	0.422	0.320	2.30

Table 27

Chemical Analyses of Sediments and Interstitial Water Taken at Various Depths at Location 2, an Intermediate Location from the Bolivar Peninsula Study Site

Sediment Analysis

Core Section (cm)	Calcium (μg/g)	Potassium (μg/g)	Sodium (μg/g)	Magnesium (μg/g)	Iron (μg/g)	Manganese (μg/g)	Zinc (μg/g)	Copper (μg/g)	Lead (μg/g)	Cadmium (μg/g)	Mercury (μg/g)	Sulfide (μg/g)	Cation Exchange Capacity (meq/100g)
0-10	12,090	5,230	3,110	850	3,710	139	13.9	9.8	9.0	0.83	----	1.78	0.97
10-35	8,450	5,970	3,050	820	3,760	115	13.4	11.7	8.6	0.72	0.02	1.61	1.26
35-60	25,910	11,710	6,730	1,880	8,350	153	13.7	16.2	9.0	1.00	0.06	1.69	1.69
60-85	33,290	5,470	2,860	1,480	5,220	264	19.5	21.6	12.4	1.28	0.06	1.69	2.10
85-107	17,350	4,360	2,950	860	3,450	138	13.3	13.1	9.0	0.88	0.06	<.58	0.67

Interstitial Water Analysis

Core Section (cm)	Calcium (μg/mℓ)	Potassium (μg/mℓ)	Sodium (μg/mℓ)	Magnesium (μg/mℓ)	Iron (μg/mℓ)	Manganese (μg/mℓ)	Zinc (μg/mℓ)	Copper (μg/ℓ)	Lead (μg/ℓ)	Cadmium (μg/ℓ)	Mercury (μg/ℓ)
35-60	125	430	150	71	1.4	0.5	0.3	<7.5	<8	<1	<0.5
60-85	67	460	175	68	1.0	0.8	0.1	<7.5	<8	<1	<0.5

Table 28

Chemical and Physical Analyses of Sediments and Chemical Analysis of Interstitial Water Taken at Various Depths at Location 5, an Intermediate Location from the Bolivar Peninsula Study Site

Sediment Analysis

Core Section (cm)	Color	Moisture Content (%)	Particle-Size Distribution (%) Sand	Silt	Clay	Eh (mv)	pH	Total Organic Matter (%)	Total Organic Nitrogen (mg/kg)	Ammonium (mg/kg)	Extractable Ortho-phosphate (mg/kg)
0-10	10 YR 4/2	20.5	97.08	2.50	0.00	+456	7.30	0.40	238.2	<0.30	0.383
10-35	10 YR 5/2	22.3	97.98	0.00	1.25	+476	7.70	0.24	137.4	6.41	0.167
35-60	10 YR 4/2	18.1	98.08	0.00	1.25	+346	7.70	0.03	21.0	<0.30	0.125
60-85	10 YR 5/1	19.1	98.04	1.25	0.00	+286	7.40	0.04	18.5	<0.30	0.133
85-107	10 YR 5/1	18.9	98.59	1.25	0.00	+ 11	7.70	0.02	19.9	<0.30	0.325

Interstitial Water Analysis

Core Section (cm)	Ammonium-N (mg/ℓ)	Nitrate-N (mg/ℓ)	Nitrate-N (mg/ℓ)	Total Inorganic Nitrogen (mg/ℓ)	Total Phosphorus (mg/ℓ)	Ortho-phosphate (mg/ℓ)	Organic Carbon (mg C/ℓ)
0-10	0.02	0.74	0.005	0.76	---	<0.030	8.76
10-35	---	0.59	0.005	0.60	0.139	<0.030	4.10
35-60	0.12	0.24	0.005	0.36	0.132	<0.030	4.42

Table 29

Chemical Analyses of Sediments and Interstitial Water Taken at Various Depths at Location 5, an Intermediate Location from the Bolivar Peninsula Study Site

Sediment Analysis

Core Section (cm)	Calcium (μg/g)	Potassium (μg/g)	Sodium (μg/g)	Magnesium (μg/g)	Iron (μg/g)	Manganese (μg/g)	Zinc (μg/g)	Copper (μg/g)	Lead (μg/g)	Cadmium (μg/g)	Mercury (μg/g)	Sulfide (μg/g)	Cation Exchange Capacity (meq/100g)
0-10	6,890	3,830	3,150	1,110	3,950	108	17.4	16.4	12.0	0.64	0.04	<.58	1.38
10-35	6,230	2,490	3,050	720	3,300	91	14.0	15.6	9.0	0.41	0.05	<.58	1.74
35-60	7,070	2,990	2,990	650	3,180	104	16.1	45.9	8.2	0.65	0.04	<.58	0.22
60-85	7,870	4,730	3,670	1,160	4,400	106	16.2	13.2	10.2	0.75	0.06	<.58	0.19
85-107	7,840	4,990	3,080	690	3,100	88	11.6	9.9	8.6	0.65	0.04	<.58	0.11

Interstitial Water Analysis

Core Section (cm)	Calcium (μg/mℓ)	Potassium (μg/mℓ)	Sodium (μg/mℓ)	Magnesium (μg/mℓ)	Iron (μg/mℓ)	Manganese (μg/mℓ)	Zinc (μg/mℓ)	Copper (μg/mℓ)	Lead (μg/ℓ)	Cadmium (μg/ℓ)	Mercury (μg/ℓ)
35-60	140	380	240	60	2.5	1.5	0.6	<7.5	<8	<1	<0.5
60-85	140	380	235	58	10.2	1.4	0.6	<7.5	<8	<1	<0.5

Table 30

Chemical and Physical Analyses of Sediments and Chemical Analysis of Interstitial Water Taken at Various Depths at Location 8, an Intermediate Location from the Bolivar Peninsula Study Site

Sediment Analysis

Core Section (cm)	Color	Moisture Content (%)	Particle-Size Distribution (%) Sand	Silt	Clay	Eh (mv)	pH	Total Organic Matter (%)	Total Organic Nitrogen (mg/kg)	Ammonium (mg/kg)	Extractable Ortho-phosphate (mg/kg)
0-10	10 YR 5/2	19.1	98.72	1.25	0.00	+276	7.00	0.09	65.8	0.36	0.167
10-35	10 YR 5/2	18.1	98.29	1.25	1.25	+216	7.45	0.08	57.7	0.36	0.067
35-60	10 YR 5/2	18.1	97.96	1.25	0.00	+196	7.40	0.03	24.6	<0.30	1.250
60-85	10 YR 5/2	18.4	98.44	0.00	1.25	+206	7.50	0.04	19.6	<0.30	0.167

Interstitial Water Analysis

Core Section (cm)	Ammonium-N (mg/ℓ)	Nitrate-N (mg/ℓ)	Nitrite-N (mg/ℓ)	Total Inorganic Nitrogen (mg/ℓ)	Total Phosphorus (mg/ℓ)	Ortho-phosphate (mg/ℓ)	Dissolved Organic Carbon (mg C/ℓ)
0-10	0.02	0.42	0.010	0.45	--	0.155	9.55
10-35	0.12	0.23	<0.005	0.35	--	0.155	6.69
35-60	0.20	0.36	<0.005	0.56	2.090	0.075	5.30
60-85	0.12	1.00	<0.005	1.12	0.598	0.075	4.80

Table 31

Chemical Analyses of Sediments and Interstitial Water Taken at Various Depths at Location 8, an Intermediate Location from the Bolivar Peninsula Study Site

Sediment Analysis

Core Section (cm)	Calcium (μg/g)	Potassium (μg/g)	Sodium (μg/g)	Magnesium (μg/g)	Iron (μg/g)	Manganese (μg/g)	Zinc (μg/g)	Copper (μg/g)	Lead (μg/g)	Cadmium (μg/g)	Mercury (μg/g)	Sulfide (μg/g)	Cation Exchange Capacity (meq/100g)
0-10	6,440	4,730	2,930	690	3,100	83	13.0	13.7	10.2	0.76	0.05	0.66	0.88
10-35	11,000	8,920	7,560	1,830	7,990	80	16.0	21.8	8.6	0.74	0.02	0.62	1.35
35-60	7,470	6,470	2,920	660	3,300	81	12.8	12.4	8.6	0.72	0.05	<0.58	0.82
60-85	7,410	6,460	2,920	610	3,090	91	12.7	13.7	8.2	0.70	0.03	<0.58	0.83

Interstitial Water Analysis

Core Section (cm)	Calcium (μg/mℓ)	Potassium (μg/mℓ)	Sodium (μg/mℓ)	Magnesium (μg/mℓ)	Iron (μg/mℓ)	Manganese (μg/mℓ)	Zinc (μg/mℓ)	Copper (μg/ℓ)	Lead (μg/ℓ)	Cadmium (μg/ℓ)	Mercury (μg/ℓ)
35-60	105	430	345	105	6.8	0.7	0.9	<7.5	<8	<1	<0.5
60-85	88	460	1,375	115	8.3	2.8	5.0	<7.5	<8	<1	<0.5

responding low values for organic nitrogen. The two upper sections of core 5 were higher in organic matter with 0.40 and 0.24 percent for the 0-10 and 10-35 cm depths, respectively. Corresponding organic nitrogen concentrations were also high in these two sections with values of 238.2 and 137.4 mg N/kg.

113. Extractable ammonium-N was relatively low at all depths in the profiles except for the 10-35 cm section of core 5. The high value of 6.41 mg N/kg is unexplained.

114. Water-soluble phosphorus values were variable and not particularly related to depth. Concentrations ranged from 0.067 to 1.25 mg P/kg.

115. Cation exchange capacity of these sediment samples were very low and ranged from 0.11 to 2.10 meq/100 g soil.

116. Sulfide content was low in all profiles. The profile at location 2 had higher values than profiles at either location 5 or 8.

117. Fertility analysis on the top section of each of the three intermediate cores showed the same trends as the cores from the upland sites. Calcium and magnesium values were high whereas phosphorus and potassium values were low to very low. Zinc, iron, and manganese values were also high.

118. Total metal analysis on the core sections was similar to the cores from the upland sites of the study area. Calcium values at location 2 were very high opposed to locations 5 and 8. This is again due to the amount of shell material found in the core. The ranges of the other metals were similar to the upland cores and are documented in Tables 27, 29, and 31.

119. Interstitial water analyses were performed for those core sections where water could be extracted in the field. With the exception of the 0-10 and 10-35 cm section of core 2, some interstitial water was extracted at all depths which could be hand-sampled in the PVC pipes.

120. Concentrations of ammonium-, nitrate-, and nitrite-N in the interstitial water were generally low. Modest amounts of nitrate-N were present at all depths, but in general, concentrations of ammonium- and nitrite-N were barely detectable.

121. Total phosphate and orthophosphate concentrations in the interstitial water were generally low. When higher concentrations of

total phosphorus were present, they were associated with higher orthophosphate concentrations in solution. Interstitial water from core 5 was low in total phosphate as well as inorganic orthophosphate.

122. Dissolved organic carbon values were in the normal range for sediments. They ranged from 2.30 to 9.55 mg C/ℓ. Concentration of dissolved organic carbon tended to decrease with increasing depth.

123. Metal analysis on the interstitial water samples taken from locations 2, 5, and 8 were low compared to the metal content of the surrounding sediments. Cadmium values were less than one μg/ℓ, lead values less than 8 μg/ℓ and copper values were also low. Mercury values were all less than 0.5 μg/ℓ. The sodium content of the interstitial water taken from location 8 at a depth of 60-85 cm is high compared to the rest of the interstitial water samples. This is most likely due to the influence of sea water mixing in at these lower depths.

Lowland sites

124. Sediment cores were taken in the intertidal area during periods of low tide; analyses are in Tables 32-37. These sediments were essentially saturated with water at all times. The reduced conditions in the soil were generally apparent from the darker color of the sediments. This series of cores was grey and dark grey in color due to dissolved organic matter and sulfides (Tables 32, 34, and 36).

125. Moisture content of the sediments was generally greater than 18 percent throughout the profile. The lone exception was the 60 to 85-cm section of core 3, which had a moisture content of 15.8 percent.

126. Particle-size distribution was similar to that of cores taken from higher elevations except that there was considerably more silt present in the profiles. Percentage silt ranged from a low of 1.25 to a high of 7.5 percent. The percentage of clay also tended to be higher on the lowland sites compared to the other two sampling elevations.

127. Eh values were all negative, indicating the lack of oxygen throughout these profiles. There was a tendency for lower Eh readings at increasing depths for all profiles. This was expected since there would be some dissolved oxygen movement into the upper portions of the profile with the surface water.

128. pH values were generally higher than those recorded for the other locations. The lowest pH value was 7.40 and the highest was 8.40.

Table 32

Chemical and Physical Analyses of Sediments and Chemical Analysis of Interstitial Water Taken at Various Depths at Location 3, a Location Below Mean High Tide at the Bolivar Peninsula Study Site

Sediment Analysis

Core Section (cm)	Color	Moisture Content (%)	Particle-Size Distribution (%) Sand	Silt	Clay	Eh (mv)	pH	Total Organic Matter (%)	Total Organic Nitrogen (mg/kg)	Ammonium (mg/kg)	Extractable Ortho-phosphate (mg/kg)
0-10	10 YR 5/1	18.4	97.81	1.25	0.00	+ 96	7.60	0.06	23.1	<0.30	0.167
10-35	10 YR 5/1	18.6	97.76	2.50	0.00	+ 46	7.70	0.05	27.4	<0.30	0.158
35-60	7.5 YR 4/0	19.2	93.57	5.00	1.25	-209	8.30	0.15	153.8	<0.30	1.291
60-85	7.5 YR 4/0	15.8	93.93	3.75	2.50	- 94	8.30	0.08	42.4	<0.30	0.167
85-107	2.5 YR 4/0	18.9	94.04	5.00	0.00	-104	8.40	0.12	63.4	<0.30	0.208

Interstitial Water Analysis

Core Section (cm)	Ammonium-N (mg/ℓ)	Nitrate-N (mg/ℓ)	Nitrite-N (mg-ℓ)	Total Inorganic Nitrogen (mg/ℓ)	Total Phosphorus (mg/ℓ)	Ortho-phosphate (mg/ℓ)	Dissolved Organic Carbon (mg C/ℓ)
0-10	0.59	0.83	<0.005	1.42	0.442	0.445	7.30
10-35	4.03	1.12	0.025	5.15	2.100	0.645	6.25
35-60	3.68	2.45	0.023	6.13	3.250	0.525	4.95

Table 33

Chemical Analyses of Sediments and Interstitial Water Taken at Various Depths at Location 3, a Location Below Mean High Tide at the Bolivar Peninsula Study Site

Sediment Analysis

Core Section (cm)	Calcium (μg/g)	Potassium (μg/g)	Sodium (μg/g)	Magnesium (μg/g)	Iron (μg/g)	Manganese (μg/g)	Zinc (μg/g)	Copper (μg/g)	Lead (μg/g)	Cadmium (μg/g)	Mercury (μg/g)	Sulfide (μg/g)	Cation Exchange Capacity (meq/100g)
0-10	5,150	5,990	4,180	970	3,270	99	13.6	14.0	8.2	0.70	0.08	1.26	0.85
10-35	6,310	5,960	4,600	1,080	3,370	105	14.0	13.4	9.8	0.70	0.04	1.88	0.71
35-60	5,680	4,340	4,030	1,180	3,900	96	18.0	24.2	10.9	0.69	0.08	2.69	1.48
60-85	7,040	6,960	4,160	1,180	4,200	117	14.9	14.0	9.8	0.79	0.06	2.40	0.36
85-107	5,820	5,440	4,020	1,250	4,180	94	17.1	19.5	11.6	0.74	0.02	4.65	1.21

Interstitial Water Analysis

Core Section (cm)	Calcium (μg/mℓ)	Potassium (μg/mℓ)	Sodium (μg/mℓ)	Magnesium (μg/mℓ)	Iron (μg/mℓ)	Manganese (μg/mℓ)	Zinc (μg/mℓ)	Copper (μg/ℓ)	Lead (μg/ℓ)	Cadmium (μg/ℓ)	Mercury (μg/ℓ)
0-10	350	710	6,300	580	1.2	0.8	2.4	<7.5	<8	<1	<0.5
10-35	295	600	4,980	470	5.0	4.5	0.2	<7.5	<8	<1	<0.5
35-60	270	590	4,550	430	5.6	12.7	0.3	<7.5	<8	<1	<0.5

Table 34

Chemical and Physical Analyses of Sediments and Chemical Analysis of Interstitial Water Taken at Various Depths at Location 6, a Location Below Mean High Tide at the Bolivar Peninsula Study Site

Sediment Analysis

Core Sections (cm)	Color	Moisture Content (%)	Particle-Size Distribution (%) Sand	Silt	Clay	Eh (mv)	pH	Total Organic Matter (%)	Total Organic Nitrogen (mg/kg)	Ammonium (mg/kg)	Extractable Ortho-phosphate (mg/kg)
0-10	10 YR 3/1	19.6	95.90	2.50	1.25	-174	7.40	0.80	105.4	<0.30	0.575
10-35	10 YR 4/1	20.6	96.16	2.50	1.25	-164	7.75	0.14	84.0	<0.30	0.408
35-60	10 YR 4/1	18.8	94.52	3.75	1.25	-234	7.70	0.09	52.0	<0.30	0.125
60-85	10 YR 4/1	19.0	94.64	3.75	1.25	-169	8.00	0.10	59.5	<0.30	0.415
85-107	7.5 YR 4/0	18.6	94.00	3.75	2.50	-224	7.90	0.13	82.6	0.71	0.575

Interstitial Water Analysis

Core Section (cm)	Ammonium-N (mg/ℓ)	Nitrate-N (mg/ℓ)	Nitrate-N (mg/ℓ)	Total Inorganic Nitrogen (mg/ℓ)	Total Phosphorus (mg/ℓ)	Ortho-phosphate (mg/ℓ)	Dissolved Organic Carbon (mg C/ℓ)
0-10	1.38	1.61	<0.005	3.00	1.380	0.566	6.75
10-35	2.73	0.28	<0.005	3.00	0.569	0.315	6.50
35-60	0.36	2.02	0.085	2.40	0.694	0.216	5.25

Table 35

Chemical Analyses of Sediments and Interstitial Water Taken at Various Depths at Location 6, a Location Below Mean High Tide at the Bolivan Peninsula Study Site

Sediment Analysis

Core Section (cm)	Calcium (μg/g)	Potassium (μg/g)	Sodium (μg/g)	Magnesium (μg/g)	Iron (μg/g)	Manganese (μg/g)	Zinc (μg/g)	Copper (μg/g)	Lead (μg/g)	Cadmium (μg/g)	Mercury (μg/g)	Sulfide (μg/g)	Cation Exchange Capacity (meq/100g)
0-10	8,610	4,600	3,420	1,000	5,910	129	14.9	11.5	9.3	0.76	0.02	1.26	1.01
10-35	5,280	5,960	4,910	1,320	4,010	109	16.3	16.5	11.3	0.75	0.05	2.45	1.10
35-60	6,940	6,970	4,290	1,490	5,330	130	18.0	14.4	11.0	0.83	0.08	2.31	3.84
60-85	6,270	7,220	4,360	1,270	4,560	104	17.3	15.1	8.9	0.65	0.07	0.83	0.24
85-107	7,060	7,720	4,600	1,540	5,560	110	20.2	19.7	10.6	0.92	0.04	2.26	1.43

Interstitial Water Analysis

Core Section (cm)	Calcium (μg/mℓ)	Potassium (μg/mℓ)	Sodium (μg/mℓ)	Magnesium (μg/mℓ)	Iron (μg/mℓ)	Manganese (μg/mℓ)	Zinc (μg/mℓ)	Copper (μg/ℓ)	Lead (μg/ℓ)	Cadmium (μg/ℓ)	Mercury (μg/ℓ)
0-10	340	690	5,700	560	1.8	7.2	0.6	<7.5	<8	<1	<0.5
10-35	270	640	4,800	460	1.5	1.4	0.1	<7.5	<8	<1	<0.5
35-60	270	620	4,850	430	1.9	2.2	0.2	<7.5	<8	<1	<0.5

Table 36

Chemical and Physical Analyses of Sediments and Chemical Analysis of Interstitial Water Taken at Various Depths at Location 9, a Location Below Mean High Tide at the Bolivar Peninsula Study Site

Sediment Analysis

Core Section (cm)	Color	Moisture Content (%)	Particle-Size Distribution (%) Sand	Silt	Clay	Eh (mv)	pH	Total Organic Matter (%)	Total Organic Nitrogen (mg/kg)	Ammonium (mg/kg)	Extractable Ortho-Phosphate (mg/kg)
0-10	5 YR 5/1	23.[illegible]	90.14	7.36	2.50	+ 36	7.50	0.22	115.4	1.78	0.292
10-35	5 YR 4/1	20.2	88.47	7.50	3.75	+ 86	8.40	0.12	49.5	<0.30	0.292
35-60	5 YR 5/1	19.5	95.90	2.50	1.25	-114	8.20	0.09	40.6	<0.30	0.158
60-85	5 YR 5/1	18.7	93.44	3.75	2.50	-144	8.30	0.12	61.9	1.42	0.208
85-107	5 YR 4/1	18.3	91.24	7.50	1.25	-199	7.90	0.15	67.9	<0.30	0.083

Interstitial Water Analysis

Core Section (cm)	Ammonium-N (mg/ℓ)	Nitrate-N (mg/ℓ)	Nitrite-N (mg/ℓ)	Total Inorganic Nitrogen (mg/ℓ)	Total Phosphorus (mg/ℓ)	Ortho-phosphate (mg/ℓ)	Dissolved Organic Carbon (mg C/ℓ)
0-10	1.31	0.58	<0.005	1.90	0.622	0.625	4.64
10-35	3.18	2.96	<0.005	6.14	0.070	0.025	4.74
35-60	0.14	2.24	<0.005	2.40	1.512	0.488	5.10

Table 37

Chemical Analyses of Sediments and Interstitial Water Taken at Various Depths at Location 9, a Location Below Mean High Tide at the Bolivar Peninsula Study Site

Sediment Analysis

Core Section (cm)	Calcium (μg/g)	Potassium (μg/g)	Sodium (μg/g)	Magnesium (μg/g)	Iron (μg/g)	Manganese (μg/g)	Zinc (μg/g)	Copper (μg/g)	Lead (μg/g)	Cadmium (μg/g)	Mercury (μg/g)	Sulfide (μg/g)	Cation Exchange Capacity (meq/100g)
0-10	6,070	5,340	4,600	1,430	4,900	118	20.3	24.2	11.7	0.76	0.03	3.15	2.78
10-35	7,500	4,100	6,200	1,810	5,620	146	19.4	18.4	9.3	0.76	0.05	2.66	1.92
35-60	5,300	3,490	5,360	1,330	4,140	103	16.9	18.8	9.3	0.70	0.06	2.63	1.54
60-85	6,580	6,590	4,910	1,280	4,330	102	17.3	19.0	9.8	0.76	0.02	2.29	1.55
85-107	6,580	7,840	5,170	1,640	5,580	130	21.2	27.8	14.8	0.82	0.04	2.20	2.43

Interstitial Water Analysis

Core Section (cm)	Calcium (μg/mℓ)	Potassium (μg/mℓ)	Sodium (μg/mℓ)	Magnesium (μg/mℓ)	Iron (μg/mℓ)	Manganese (μg/mℓ)	Zinc (μg/mℓ)	Copper (μg/ℓ)	Lead (μg/ℓ)	Cadmium (μg/ℓ)	Mercury (μg/ℓ)
0-10	340	650	5,750	570	1.8	6.2	3.0	<7.5	<8	<1	<0.5
10-35	300	580	4,600	440	2.0	8.8	0.1	<7.5	<8	<1	<0.5
35-60	280	620	4,630	450	2.1	6.7	0.1	<7.5	<8	<1	<0.5

129. Total organic carbon and total organic nitrogen followed trends similar to those reported for the previous sites. Exchangeable NH_4^+-N was low except for two horizons of core 9 where 1.78 and 1.42 mg/kg were recorded for the 0 to 10-and 60 to 85-cm sections, respectively.

130. Extractable orthophosphate was generally between 0.1 and 0.6 mg/kg. A value of 1.29 mg/kg was recorded for the 35 to 60 cm section of core 3.

131. Sulfide content was again low at each location but was higher than either the upland or intermediate sites. Values ranged from 0.83 μg/g to 4.65 μg/g. These higher values reflect the reducing conditions found at these lowland sites.

132. Cation exchange capacity was low as were the values from the upland and intermediate sites. Cation exchange values for the lowland sites ranged from 0.20 to 3.84 meq/100 g soil.

133. Fertility data on the lowland sites was somewhat different from that reported for the intermediate and upland sites. Calcium values were very high (>6000 #Ca/A). Magnesium values at locations 3, 6, and 9 were higher than those values from the other areas of the study site. Magnesium values at the lowland sites were greater than 500 pounds per acre. Phosphorus values were low and about the same as phosphorus values from the upland and intermediate sites. Potassium values from locations 3, 6, and 9 were high compared to potassium values from the rest of the study site. The lowland sites also had high sodium values and a medium salinity hazard as opposed to the upland and intermediate sites.

134. Metal concentrations at all three lowland locations were similar to values from those cores taken from the remaining study area. Calcium values on the lowland sites are not as variable as those from previous locations. This is probably an indication of more homogeneous core structures at the lowland sites. The magnesium and sodium values for the lowland sites appeared to be higher than the values from the upland and intermediate sites. This was probably due to the direct influence sea water has on the lowland cores in increasing the magnesium and sodium concentrations. Cadmium values were usually less than 0.8 μg/g and lead values averaged around 10 or 11 μg/g. Mercury values ranged from 0.02 to 0.08 μg/g.

135. Interstitial water samples from the lowland sites below mean high tide were collected from the top three sections. Both ammonium-N and nitrate-N concentrations were higher in these samples than for samples from similar depths at the intermediate elevations. For all three profiles, the concentration of ammonium-N was highest in the 10-35-cm section. Nitrite-N was low in these profiles with the highest concentration being 0.085 mg/ℓ.

136. Total phosphate and orthophosphate concentrations were also higher at these locations than for those at intermediate elevations. Concentrations as high as 3.25 mg/ℓ were measured at the 35- to 60-cm depth for core 3, and generally the values were above 0.4 mg/ℓ with corresponding orthophosphate concentrations of 0.2 mg/ℓ and greater. Core 9 had only 0.09 mg/ℓ total phosphate and 0.025 mg/ℓ orthophosphate in the 10-to 35-cm depth.

137. Dissolved organic carbon was between 4.64 and 7.30 mg/ℓ in all interstitial water samples for the lowland sites. These values could be classified as normal for these sediments.

138. Metal analysis on the interstitial water samples taken from the lowland sites are shown in Tables 33, 35, and 37. Calcium, potassium, sodium and magnesium values were all higher than interstitial water values taken at the intermediate sites. This is expected since the lowland sites are in contact with sea water which causes the increases found in the major cations (Ca, K, Na, Mg). Upland areas are partially leached of those cations due to movement of rain water through the profile. Manganese concentrations in interstitial water from the lowland sites are also somewhat higher than at the intermediate sites. Copper, zinc, lead, cadmium, and mercury values at the lowland locations are similar to those found at the intermediate sites.

PART VII: CONCLUSIONS

139. A total of 74 plant species representing 61 genera and 20 families were collected and identified from the study site during a 5-month summer and early fall period. Gramineae, Compositae, and Cyperaceae were the most important families. The average basal cover was over 13 percent with litter cover exceeding 15 percent. The dominant grasses were marshay and bluestem. Forb density was over 10 plants/square foot; camphorweed was the most commonly occurring species. Woody plant density exceeded 3,200 plants/acre with drummond sesbania the most common species. The only other woody species to occur was gulf croton.

140. Six plant communities were identified and mapped. These were, in order of area occuppied: (a) Andropogon perangustatus, (b) Spartina patens, (c) Sesbania-mixed grass, (d) Sporobolus virginicus-Distichlis spicata, (e) Monarda citriodora, and (f) Spartina alterniflora. Biomass production exceeded 4,100 pounds/acre in both the Andropogon perangustatus and Spartina patens communities.

141. Bird species recorded increased from 41 in July to 50 in September, totalling 98. Red-winged blackbirds were the most numerous species. Thirteen mammal species were recorded, three of them domestic. The most common were hispid cotton rats, raccoon, and domestic goat. The cotton rat population was estimated at an average of 30/acre. A total of 31 reptiles and amphibians representing 11 species were observed on the study site. Eighteen orders of macroinvertebrates were collected and identified. The most common forms were grasshoppers, land snails, mud fiddler crabs, and tiger beetles.

142. All soil and sediment samples in the study site were sandy to a depth of 107 cm, ranging from 88 to 99 percent sand. Total organic carbon was less than 0.2 percent except where evidence of some plant residue occurred. Values of Eh varied from +500 mv for oxidized horizons to near -240 mv in the intertidal zone. The Eh was related to soil moisture content.

143. Interstitial water samples did not contain excessive concentrations of ammonium, nitrite-, or nitrate-N. Total inorganic nitrogen did not exceed 6.14 mg/ℓ. Total phosphorous and orthophosphate concentrations in interstitial water were less than 3.25 and 9.625 mg/ℓ, respectively. Total dissolved carbon ranged between 2.0 and 9.55 mg/ℓ.

144. Flora and fauna of the study site were low, both in terms of diversity and density. Chemical composition of the sediments corresponded to the sandy nature of the material. Excessive nutrient concentrations were not evident. Thus, the study site is below potential productivity and use for coastal marshes.

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APPENDIX A'

SPECIES LIST FOR THE BOLIVAR PENNINSULA HABITAT DEVELOPMENT SITE, GALVESTON BAY, TEXAS

Family-Scientific name	Common Name
Asclepiadaceae	
Cynanchum angustifolium Pers.	Swallowwort
Boraginaceae	
Heliotropium curassavicum L.	Salt heliotrope
Capparidaceae	
Polanisia trachysperma var. trachysperma (T.&G.) Iltis	Roughseed clammyweed
Chenopodiaceae	
Chenopodium ambrosioides L.	Wormseed goosefoot
Salicornia bigelovii Torr.	Bigelow glasswort
Commelinaceae	
Commelina angustifolia Michx.	Narrowleaf dayflower
Compositae	
Ambrosia psilostachya DC.	Western ragweed
Aphanostephus skirrhobasis var. thaliassius (DC.) Trel. Shinners	Coast dozedaisy
Conyza canadensis (L.) Cronquist	Horsetail conyza
Erechtites hieracifolia (L.) Raf.	American burnweed
Erigeron myrionactis Small	Corpus Christi fleabane
Eupatorium compositifolium Walt.	Yankeeweed
Euthamia leptocephala (T.&G.) Greene	(none)
Gaillardia pulchella Foug.	Rosering gaillardia
Helenium amarum (Raf.) H. Rock	Sneezeweed
Helianthus debilis Nutt. ssp. praecox (Engelm.&Gray) Heiser	Early cucumberleaf sunflower
Heterotheca subaxillaris (Lam.) Britt&Rusby	Camphorweed
Iva angustifolia var. angustifolia Nutt.	Narrowleaf sumpweed
Iva frutescens L.	Bigleaf sumpweed
Pluchea purpurascens (SW.) DC.	Purple pluchea
Solidago sempervirens L. var. mexicana (L.) Fern	Seaside goldenrod
Convolvulaceae	
Ipomoea sagittata Poir.	Saltmarsh morningglory

APPENDIX A' (CONTINUED)

Family-Scientific Name	Common Name
Cyperaceae	
Cyperus articulatus L.	Jointed flatsedge
Cyperus ovularis (Michx.) Torr. var. ovularis	Globe flatsedge
Cyperus ovularis (Michx.) Torr. var. cylindricus (Will.) Torr.	Cylinder flatsedge
Cyperus polystachyos Rottb.	(none)
Eleocharis albida Torr.	White spikesedge
Eleocharis macrostachya Britton	Largespike spikesedge
Fimbristylis carolinianum (Lam.)	Fimbry
Scirpus americanus Pers.	American bulrush
Euphorbiaceae	
Croton capitatus Michx.	Woolly croton
Croton punctatus Jacq.	Gulf croton
Euphorbia ammannioides T.&G.	Ingalls euphorbia
Gentianaceae	
Sabatia campestris Nutt.	Prairie rosegentian
Gramineae	
Andropogon glomeratus (Walt.) B.S.P.	Bushy bluestem
Andropogon perangustatus Nash.	Bluestem
Aristida longaespica Poir var. longaespica	Slimspike threeawn
Aristida oligantha Michx.	Old field threeawn
Cenchrus incertus M.A. Curtis	Common sandbur
Cynodon dactylon (L.) Pers.	Bermudagrass
Distichlis spicata (L.) Green var. spicata	Seashore saltgrass
Eragrostis oxylepis (Torr.) Torr.	Red lovegrass
Eragrostis silveana	(none)
Eustachys petraea (Swartz) Desv.	(none)
Muhlenbergia capillaris (Lam.) Trin.	Hairyawn muhly
Panicum repens L.	Torpedograss
Paspalum monostachyum Vassey	Gulfdune paspalum
Paspalum seteceum Michx. var. setaceum	Thin paspalum
Polypogon monspeliensis (L.) Desf.	Rabbitfoot polypogon
Setaria geniculata (Lam.) Beauv.	Knotroot bristlegrass
Spartina alterniflora Loisel.	Smooth cordgrass
Spartina patens (Ait.) Muhl.	Marshay
Spartina spartinae (Trin.) Merr.	Gulf cordgrass
Sporobolus indicus (L.) R. Br.	Smutgrass
Sporobolus pyramidatus (Lam.) Hitchc.	Whorled dropseed
Sporobolus virginicus (L.) Kunth	Seashore dropseed
Triplasis purpurea (Walt.) Chapm.	Purple sandgrass

APPENDIX A' (CONCLUDED)

Family-Scientific Name	Common Name
Labiatae	
Monarda citriodora Cerv.	Lemon beebalm
Leguminosae	
Astragalus nuttallianus DC. var. nuttallianus	Nuttail milkvetch
Cassia fasciculata Michx. var. fasciculata	Prairie senna
Medicago lupulina L.	Black medic
Neptunia lutea (Leavenw.) Benth	Yellow neptunia
Prosopis glandulosa Torr. var. glandulosa	Honey mesquite
Psoralea rhombifolia Torr. & Gray	Roundleaf scurfpea
Sesbania drummondii (Rydb.) Cory	Drummond sesbania
Trifolium sp.	
Malvaceae	
Kosteletzkya virginica (L.) Gray	Virginia saltmarshmallow
Primulaceae	
Samolus ebracteatus H.B.K. ssp. alyssoides (Heller) R. Kunth	Coast brookweed
Rubiacea	
Galium tinctorium L.	Dye bedstraw
Scrophulariaceae	
Agalinis maritima (Raf.) Raf.	Saltmarsh gerardia
Solanaceae	
Physalis viscosa L. var. spathulaefolia (Torr.) Gray	Groundcherry
Solanum elaeagnifolium Cav.	Silverleaf nightshade
Umbelliferae	
Hydrocotyle bonariensis Lam.	Largeleaf pennywort
Verbenaceae	
Lantana horrida H.B.K.	Common lantana
Phyla incisa Small	Sawtooth frogfruit
Verbena xutha Lehm.	Coarse verbena

APPENDIX B'

PHYSICAL DESCRIPTION OF SOIL CORES

Core No.	Depth (cm)	Description
1	0-25	Sand, fine grain, massive, unconsolidated.
	25-26	Sand, fine grain, dark brown clay.
	26-73	Sand, fine grain, massive, unconsolidated, organic matter, trace shells.
	73-80	Clay and sand, very fine grain, grey to brown in color.
	80-87	Sand, fine grain, massive, unconsolidated, organic matter, trace shells.
	87-107	Sand, fine grain, unconsolidated, shell fragments (dredge).
2	0-31	Sand, fine grain, massive, unconsolidated, well sorted.
	31-33	Sand and silt, fine grain, horizontal bedding.
	33-49	Sand, fine to medium grain, massive, unconsolidated, shell fragments.
	49-54	Dredge fill, poorly sorted, sand, shell fragments.
	54-59	Sand, fine to medium grain, some shell fragments.
	59-98	Sand and silt, fine to medium grain, dredged material shell fragments, mud clasts, poorly sorted.
	98-107	Sand, fine to medium grain, massive.
3	0-8	Sand, fine grain, well sorted, horizontal bedding.
	8-23	Sand, fine to medium grain, well sorted, some horizontal bedding: sand, silt, sand.
	23-60	Sand, fine grain, some silt, well sorted, trace shell fragments, some horizontal bedding.

APPENDIX B' (CONTINUED)

Core No.	Depth (cm)	Description
	60-107	Sand, fine grain, some silt, well sorted, trace shell fragments, some horizontal bedding.
4	0-10	Sand, fine grain, some organic matter, shell fragments, massive, unconsolidated.
	10-107	Sand, fine grain, massive, unconsolidated, well sorted.
5	0-4	Sand and clay, very fine grain, some organic matter.
	4-19	Sand, fine grain, massive unconsolidated.
	19-20	Sand and clay, very fine grain, some organic matter.
	20-107	Sand, fine grain, unconsolidated, some plant material.
6	0-107	Sand, fine to very fine grain, unconsolidated, well sorted, some shell fragments, some horizontal bedding down entire core, pockets of silt.
7	0-57	Sand, fine grain, massive, unconsolidated, well sorted, trace shell fragments, some organic matter.
	57-92	Sand, medium grain, massive, unconsolidated trace shell fragments, organic matter.
	92-94	Sand and silt, fine grain, some horizontal bedding, shell fragments, grey in color.
	94-107	Sand, fine grain, poorly sorted, some silt, some organic matter.
8	0-32	Sand, fine to medium grain, massive, unconsolidated, organic matter, shell fragments.
	32-34	Sand, fine grain, some horizontal bedding, some silt.
	34-107	Sand, fine to medium grain, massive unconsolidated, some organic matter, some shell fragments.

APPENDIX B' (CONCLUDED)

Core No.	Depth (cm)	Description
9	0-20	Sand, fine grain, massive, unconsolidated, well sorted, some shell fragments, some silt, some horizontal bedding.
	20-33	Sand, fine grain, some silt, well sorted, organic matter, shell fragments, some horizontal bedding.
	33-107	Sand, fine to medium grain, well sorted, some silt, organic matter, shell fragments, some horizontal bedding.

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Dodd, J D

Habitat development field investigations, Bolivar Peninsula marsh and upland habitat development site, Galveston Bay, Texas; Appendix B: Baseline inventory of terrestrial flora, fauna, and sediment chemistry / by J. D. Dodd ... [et al.], College of Agriculture, Texas A&M University, College Station, Tex. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1978.

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TECHNICAL REPORT D-78-15

HABITAT DEVELOPMENT FIELD INVESTIGATIONS, BOLIVAR PENINSULA MARSH AND UPLAND HABITAT DEVELOPMENT SITE, GALVESTON BAY, TEXAS

APPENDIX C: BASELINE INVENTORY OF AQUATIC BIOTA

by

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National Marine Fisheries Service
Southeast Fisheries Center
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Galveston, Tex. 77550

June 1978

Final Report

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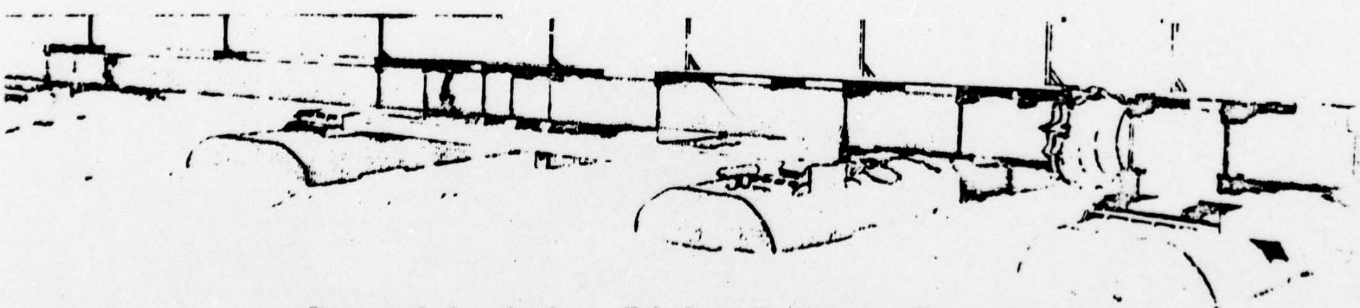

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HABITAT DEVELOPMENT FIELD INVESTIGATIONS, BOLIVAR PENINSULA
MARSH AND UPLAND HABITAT DEVELOPMENT SITE
GALVESTON BAY, TEXAS

Appendix A: Baseline Inventory of Water Quality, Sediment Quality, and Hydrodynamics

Appendix B: Baseline Inventory of Terrestrial Flora, Fauna, and Sediment Chemistry

Appendix C: Baseline Inventory of Aquatic Biota

Appendix D: Propagation of Vascular Plants and Postpropagation Monitoring of Botanical, Soil, Aquatic Biota, and Wildlife Resources

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Plankton, nekton, macrobenthos, and sediments were obtained from a bare, sandy dredged material disposal area in Galveston Bay, Texas. Samples were collected from March through October 1975 to identify, enumerate, and estimate biomass of aquatic biota prior to construction of a wave protection dike and propagation of vegetation within the dike.

This report presents the results of that study. The temporal and spatial distribution of aquatic biota and the field site are discussed. Also provided as part of this report is a bibliography of aquatic studies conducted in

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20. ABSTRACT (Continued).
Galveston Bay.

The study indicated that the abundance and diversity of aquatic biota followed expected seasonal patterns and indicated generally low levels. Spatial distribution of aquatic biota indicated greater abundance within the western half of the site.

The report recommends that sampling during future studies be conducted for a complete calendar year to substantiate suggested seasonal trends. The future sampling program should also collect during day and night to indicate diel patterns of abundance. Future studies should include the study of a relatively undisturbed area nearby to indicate biological development of the site after dike construction and plant propagation.

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SUMMARY

Plankton, nekton, macrobenthos, and sediments were inventoried from an intertidal dredged material sand flat in lower Galveston Bay, Texas. Monthly collections were conducted from March through June 1975 and then collection frequency was decreased to bimonthly through October 1975 for a total of six sample periods. The objective of the study was to identify, enumerate, and estimate the biomass of the aquatic biota using the site prior to the beginning of habitat development engineering and plant propagation activities.

The inventory revealed a generally low diversity and abundance of biota with seasonal trends in abundance that were similar to those reported in other studies of the Galveston Bay area. The sparsity of organisms in the study area appeared to be due to the absence of adequate epibenthic habitat and the susceptibility of the area to natural physical extremes, such as wind and wave action.

Phytoplankton represented the only primary producers at the field site since no submergent or emergent macrophyton were observed. Phytoplankton samples were dominated by diatoms with _Leptocylindricus minimus_ and _Asterionella japonica_ comprising over 57 percent of all phytoplankton collected. Phytoplankton concentrations were slightly higher in the eastern half of the study area.

Zooplankton samples were dominated by barnacles and copepods. These two groups represented 95 percent of the zooplankton collected. Their distribution was variable: 55 percent collected within the area to be protected, 38 percent east of the site, but only 7 percent collected in the area a short distance west of the proposed levee area.

Nekton, collected with a beam trawl, bar seine, and shrimp trawl were represented by 28 species in various life stages. _Micropogon undulatus_ and _Brevoortia patronus_ were the most abundant fishes collected. Invertebrates collected by the above gear were dominated by _Penaeus setiferus_ and _P. aztecus_ comprising 87 percent of the catch. The distribution and abundance of both vertebrate and invertebrate nekton

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appeared random throughout the study with no definite patterns detected other than expected seasonal trends in abundance.

Benthic samples were dominated by polychaetes. There were 18 polychaete species representing 43 percent of all benthic organisms collected. Density of benthos was low with only 11.9 organisms collected per litre of sediment samples. Benthic distribution was variable between transects perpendicular to and transects parallel with the shoreline. Benthic abundance was greater on the western half of the field site and at mid-depth stations and was least abundant near shore.

A general survey of oyster bed locations in Galveston Bay was also conducted and revealed that the oyster bed nearest to the field site was over 6 km away.

Measurement of the sediment organic content revealed low values (0.14 grams per litre) relative to other bay areas. The low organic content was caused by a lack of detrital material and submerged vegetation and because strong currents appeared to remove fine-grained material from much of the area. Fine-grained sediment observed in the western half of the field site was associated with a higher concentration of organic matter and greater abundance of benthos, zooplankton, meroplankton, and nekton.

PREFACE

The study reported herein was developed as part of the U. S. Army Corps of Engineers Habitat Development Project, one segment of the Dredged Material Research Program (DMRP). The DMRP was sponsored by the Office, Chief of Engineers, U. S. Army, and assigned to the Environmental Laboratory (EL) of the U. S. Army Engineer Waterways Experiment Station (WES), in Vicksburg, Mississippi.

The study was conducted under Interagency Agreement No. WESRF 75-101 by the National Marine Fisheries Service (NMFS), Southeast Fisheries Center, Galveston Laboratory, Galveston, Texas, as part of DMRP Task 4A, "Marsh Development." Field investigations were conducted along a dredged material sand flat in lower Galveston Bay, Texas, during the period from March through October 1975. Sampling was conducted during the above period to characterize the aquatic community of area prior to modification of the site by construction of a wave protection inclosure and propagation of intertidal vegetation within the inclosure.

This study was accomplished under the general supervision of Dr. J. W. Angelovic. Messrs. K. N. Baxter and J. M. Lyon provided particular assistance in coordinating the study.

This DMRP contract was managed by Mr. H. H. Allen with technical assistance from Mr. J. D. Lunz, EL. Supervision was provided by Dr. C. J. Kirby, Chief of the Environmental Resources Division, and Dr. J. H. Harrison, Chief, EL, WES. Dr. H. K. Smith was manager of the Habitat Development Project.

COL G. H. Hilt, CE, and COL J. L. Cannon, CE, were Directors of WES during the conduct of this study and the preparation of this report. Mr. F. R. Brown was Technical Director.

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CONVERSION FACTORS, METRIC (SI) TO U. S. CUSTOMARY

UNITS OF MEASUREMENT

Metric (SI) units used in this report can be converted to U. S. customary units of measurement as follows:

Multiply	By	To Obtain
Celsius degrees or kelvins	9/5	Fahrenheit degrees*
Cubic metres	35.31466	Cubic feet
Grams	0.002204622	Pounds (mass)
Kilometres	0.613711	Miles (U. S. statute)
Litres	0.2642	Gallons (U. S. liquid)
Metres	3.280839	Feet
Microns	0.00003937	Inches
Millilitres	0.0002642	Gallons
Millimetres	0.3937007	Inches
Square kilometres	0.3861021	Square miles (U. S. statute)
Square metres	10.76391	Square feet
Radians	0.0174533	Degree (angle)

*To obtain Fahrenheit (F) temperature readings from Celsius (C) readings, use the following formula: F = 9/5 (C) + 32. To obtain Fahrenheit readings from Kelvin (K) readings, use: F = 9/5 (K - 273.15) + 32.

HABITAT DEVELOPMENT FIELD INVESTIGATIONS,
BOLIVAR PENINSULA MARSH AND UPLAND HABITAT
DEVELOPMENT SITE, GALVESTON BAY, TEXAS

APPENDIX C: BASELINE INVENTORY OF AQUATIC BIOTA

Introduction

1. An inventory and assessment of aquatic biota was conducted by the National Marine Fisheries Service (NMFS) to provide an indication of the abundance and distribution of estuarine organisms occurring within the intertidal area adjacent to a dredged material disposal site in Galveston Bay, Texas. The objective of the inventory was to provide baseline data prior to construction of a wave protection inclosure and propagation of vegetation within the inclosure. A pilot study was conducted in March 1975 to provide insight into a proposed sample design. Following the pilot study, sampling was conducted in April, May, June, August, and October 1975 (Table A1).* To supplement data gained during the field sampling program, a literature search was conducted and results of this search are presented in Appendix B'.

2. The study site is located on the bay side of Bolivar Peninsula about 7 km east of the western end of the peninsula (Figure 1). The area is a long sand flat approximately midway between Baffle Point and the Gulf Intracoastal Waterway (GIWW) channel cut at Sievers Cove (Figure 1). The study site is situated on an open bay margin of sand flat with low, man-made dunes projecting into the bay at points where dredged material was released during earlier dredging disposal operations. Erosion from rain and prevailing winds has caused more of the barrier island dredged sand to drift from the dunes into the bay. On a number of occasions, strong surges of water were observed at times of sampling. At one point the water suddenly receded an estimated 10 m from the shoreline with more than a 0.15-m decrease in elevation. Within several minutes the water surged back as if it were affected by a passing ship. No ships were seen during these times, and other than the GIWW on the southern side of the island, the closest channel is the Houston Ship

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*Tables A1 through A9 are located in Appendix A' of this report.

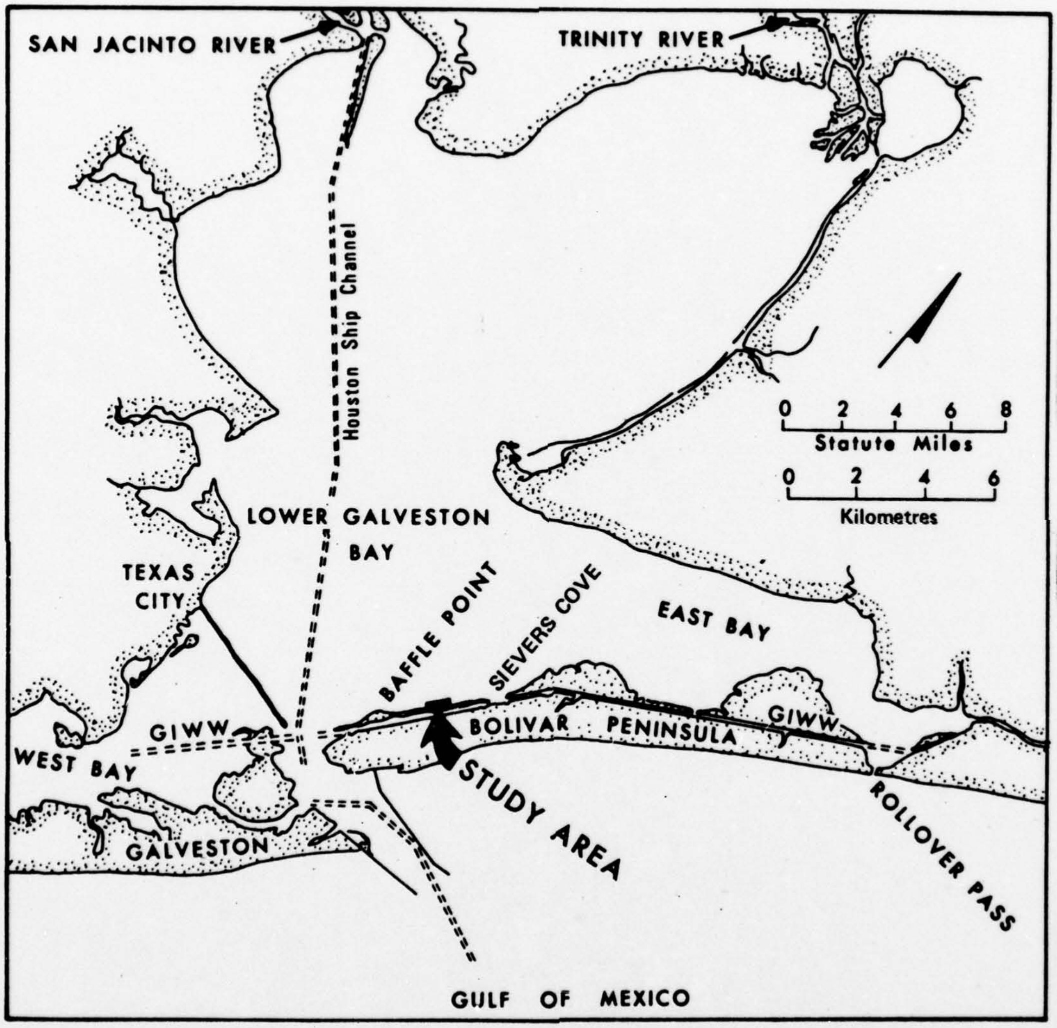

Figure 1. The study site on Bolivar Peninsula in Galveston Bay, Texas

Channel some 8 km away. This surging of water was strong enough to cause stirring and removal of fine sediments. Configuration of the projecting sand plumes indicated an east-to-west movement of prevailing currents. The exposed nature of the area and prevailing currents tend to restrict the sediments to larger particles.

3. Physical parameters of the study site are similar to those of a lagoon system (Emery et al. 1957) with sandy bottom and accompanying currents, long stretches of open straight shoreline, little depth and gradient, and practically no epibenthic life. It is not a typical estuarine situation, but rather a euryhaline transitional zone at a junction of East Bay, Lower Galveston Bay, and open gulf waters. Salinities taken on sampling dates of high standing tide ranged from 10 to 25 parts per thousand (ppt) (Table A2). Pullen and Trent (1969) recorded salinities at the site in 0.6 m of water during 1963-64 and reported a range of 16.1 to 32.4 ppt. Available data reflect a salinity regime from an upper bay environment to a gulf water environment and suggest that species not able to move in and out of the area are restricted to euryhaline forms. Lower salinity waters resulting from dilution by Trinity and San Jacinto River discharges and immediate area runoff also contribute to the wide-ranging salinity regime. Shallowness of the area causes considerable influence from the freshwater sources as well as from northerly winds. These winds can drop temperatures rapidly and expose vast portions of the sand flat leaving no escape route for aquatic organisms except toward mid-bay.

Materials and Methods

Sampling locations

4. A total of 12 sampling stations were established within the immediate vicinity of the originally proposed wave protection inclosure. (The levee inclosure was relocated later in the study and three additional stations were established.) The 12 stations were distributed along four transects perpendicular to shore, each with three stations, which formed three transects parallel to shore, each with four stations (Figure 2).

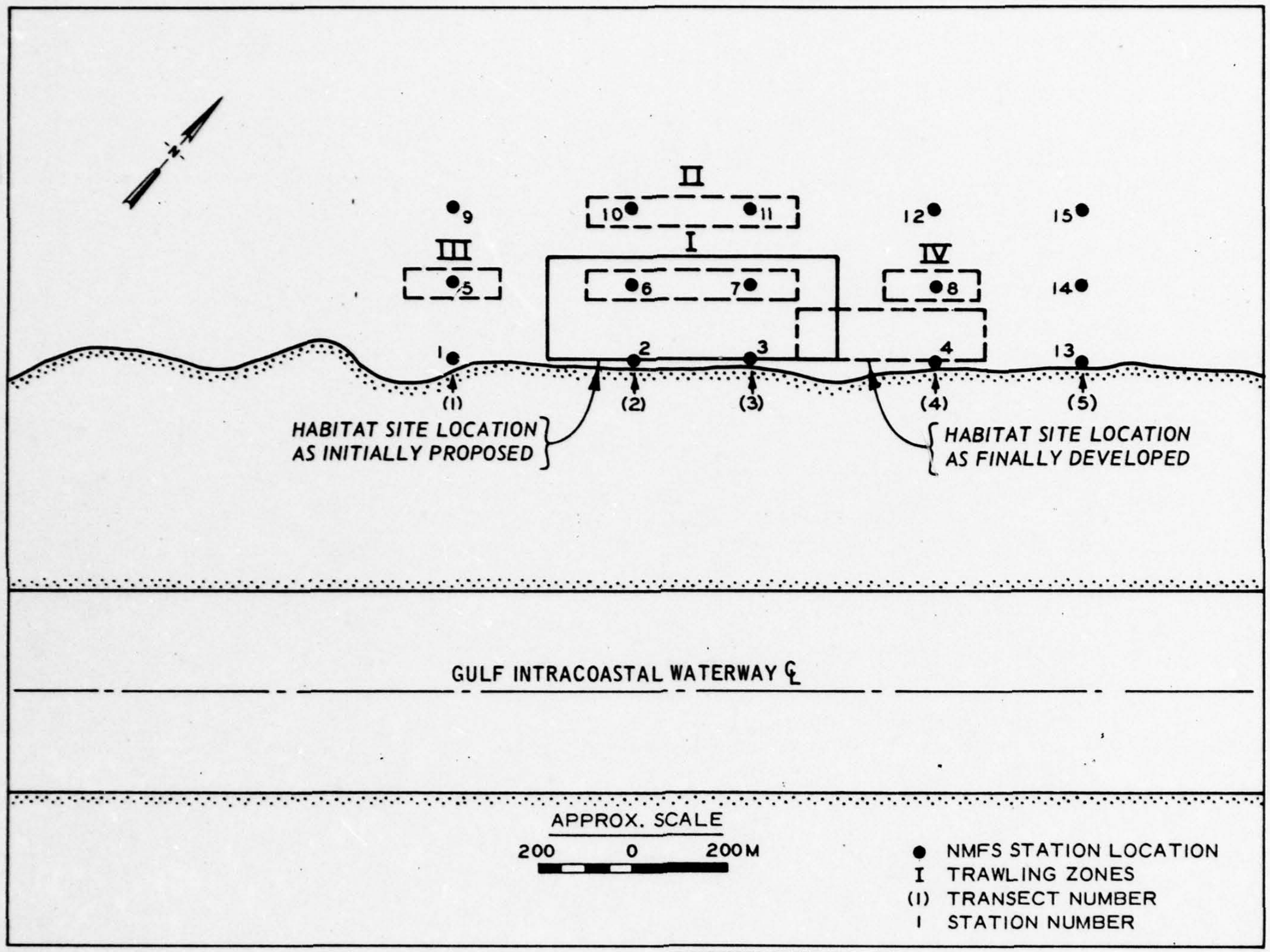

Figure 2. Location of sampling stations, transects and zones

All of the 12 stations were sampled for benthos and sediment characteristics but only the four near-shore stations were sampled for meroplankton and postlarval nekton as indicated in Table A1. In conjunction with the 12 sample stations, four trawling zones were established for the collection of phytoplankton, zooplankton, and nekton. Zone I was located inside the proposed wave protection inclosure, Zone II directly offshore, Zone III to the west, and Zone IV to the east of the study area (Figure 2).

5. The locations of the stations and zones described above were selected in relation to the originally proposed location of the levee inclosure. However, in July 1975 the NMFS was informed that a new location for the inclosure had been selected approximately 300 m east of the original site. NMFS, therefore, established three more sample stations along one transect (the fifth) perpendicular to the shore (Figure 2). This additional transect was approximately 300 m from transect 4.

Sampling Schedule

6. A pilot study was conducted in March 1975 to determine potential necessary changes in sample station locations and sampling techniques and to define macrohabitats. Following the pilot study, samples were collected monthly from April through June and in August and October 1975 (Table A1). Exceptions to the above schedule are pointed out below.

Phytoplankton

7. Phytoplankton samples were obtained during the first four collection periods (including the pilot samples in March). After the collections in June 1975, sampling of phytoplankton was terminated.

8. One-litre whole water samples were collected and preserved in five percent formalin buffered with tris (hydroxy-methyl) aminomethane and taken to the laboratory for processing. Counts were made with a Palmer-Maloney counting cell and a phase contrast microscope. Phytoplankton data represent counts of seven or fourteen preparations calculated to give the number per millilitre. Seven preparations represent a total volume of 0.1 ml. Counts that are less than 100/ml are based on the observations of one specimen of that species in the total number of preparations counted. Many of the organisms observed occurred in

various colonial forms. For these, the individual cells and not the colony were counted.

Zooplankton

9. Duplicate zooplankton samples were taken in each of the four zones during the first four sample periods; zooplankton sampling was restricted to Zones I and II in August and October 1975.

10. Samples obtained during the March pilot study were collected with a 153μ plankton net. However, the mesh clogged and was replaced with a ½-m, 243μ mesh net for subsequent samples. Each net used was equipped with a flowmeter. The net was towed for one minute, the meter reading recorded, and the samples extracted and preserved in five percent buffered formalin. Processing the samples in the laboratory consisted of recording a 24-hr settle volume, taking aliquots, allowing them to settle for 24 hrs, and reading the volume. Numbers of organisms counted were adjusted to cubic metres of water strained. Counting was done with a dissecting microscope and a Sedgewick-Rafter counting cell.

Nekton

11. Nekton samples were collected from the four zones during five of the six sample periods (no samples were obtained in May) with a 3-m-wide flat shrimp trawl made of 25-mm stretch mesh. Two shrimp trawl samples were taken at each of the four zones. Nets were towed for five minutes and covered a distance of approximately 200 m. Distance was determined by towing between station stakes. The second tow was made in the opposite direction from the first. Trawled samples were iced and taken fresh to the laboratory where they were kept refrigerated or frozen until processing could be done. At the laboratory species were identified and enumerated, and the range of length (Tables A3 and A4) and weight per species were determined.

12. Samples of juvenile nekton were taken at shoreline stations 1 through 4 in March, April, June, August, and October. Station 13 was added in October. A 15-m, 13-mm stretch mesh bar seine (a net with neither pocket nor bag and hung on bars, not points) was towed along shore a distance of 45 m, brought ashore, and the sample removed and

treated as above. The organisms were later identified and counted and range of lengths recorded. Meroplankton and postlarval fishes also were sampled at all shore stations. They were collected with a 1.8-m beam trawl (Renfro 1963) that consisted of a 1.3-m-wide body of 0.47-mm mesh and a number one mesh plankton net with detachable cod end bucket. The net was towed slowly in a semicircle guided by a 45-m length of line staked at the shoreline. The line caused a 180^0 arc to be completed 90 m along the shore from the starting point. Samples were then removed and preserved in five percent formalin until identified by species and counted at the laboratory.

Benthos

13. Benthic samples were taken in March, April, June, August, and October at all stations except stations 13, 14, and 15, which were sampled after they were added in October. Samples were taken with an Ekman dredge mounted on a galvanized pipe to aid penetration of the substrate. Duplicate grabs were made at each station. Each sample was separated into halves with one half used for benthos identification and enumeration and the other for determination of organic content. This system provided two taxonomic samples and two samples for organic content from each station. The samples were kept fresh in ice chests and refrigerated until processed.

14. Laboratory processing of benthic samples began by determining sediment volume. The March pilot study indicated accurate readings of the graduated cylinders containing sediment samples could be obtained after a 10-min settling period. A settling period of one-half hour did not appear to change the reading significantly. Next, samples were sieved through a 0.5-mm screen, and the retained material was preserved in 70 percent ethanol and examined under a dissecting microscope. Rose Bengal stain was applied to the sample after the first scanning. The sample was then reexamined to determine if any organisms or fragments remained. Finally, benthic organisms were classified to the lowest practical taxonomic level, usually species.

Sediment analysis

15. Samples for characterization of sediment organic content were

collected in duplicate in conjunction with the benthic samples as discussed above. Each of the duplicate samples was dried at $60^{0}C$ for a minimum of 24 hrs, then ashed at $500^{0}C$ for an additional 24 hrs. Procedures followed were those recommended by the National Research Council, National Academy of Sciences Biological Methods Panel Committee on Oceanography (1969). Temperatures were selected as the maximum ones that could be used without causing a breakdown of lipids when drying and carbonates when ashing.

Results and Discussions

Phytoplankton

16. Table 1 contains the mean number of diatoms per millilitre by month with all zones combined. Detailed data are available in Table A5. The eight most abundant genera and species that made up 94 percent of the total are listed separately (Table 1) while all others are combined. It is quite evident that a spring bloom occurred in April with *Leptocylindrus minimus* representing the most abundant organism. Organisms listed in these tables are ones expected and are of normal densities.

17. There were no submergent or emergent macrophyton in the sample area. Phytoplankton, therefore, were the only primary producers found. Species abundance, when compared with other studies of Galveston Bay (Copeland and Bechtel 1971), gives no indication of water-quality problems in the study area.

Zooplankton

18. Seasonal difference in the zooplankton data followed the expected pattern of spring abundance, especially in barnacle cypris larvae collected in March and April. These two major groups, barnacles and copepods, made up 95.1 percent of all zooplankton organisms counted; polychaetes accounted for 4.6 percent; and all other groups combined accounted for 0.3 percent (Table 2). Zone 1 samples contained 62 percent of all barnacle larvae, 42 percent of the copepods, 71 percent of the polychaete larvae, and 49 percent of all other organisms counted.

Higher catches of zooplankton in Zone I, as compared with catches in other zones, may have been due to eddying currents in this zone. The August and October data from Zones I and II did not differ from previous data except for an increase in numbers of copepods in the fall samples (Table A6). This seasonal increase conforms to other recorded data of both phytoplankton and zooplankton and therefore is not considered unusual. Copeland and Fruh (1970) found copepods to be the most abundant organism in East Bay samples with barnacles the second most abundant group. Although this study's sampling methods differed from theirs, similar results were obtained; copepods were the most abundant zooplankton collected in this study except during the spring (April) when barnacle larvae collected in Zone I were most abundant.

Nekton

19. Various life stages of nektonic organisms were collected in three types of sampling gear: 1.8-m beam trawl; 15-m bar seine; and a 3-m shrimp trawl. This beam trawl was selective for meroplanktonic postlarval forms. A species usually occurred first in beam trawl shore samples as postlarvae (Table 3) then in the bar seine as young juveniles (Table 4), and last in shrimp trawl samples as late juveniles and young adults (Table 5). For example, in March postlarval brown shrimp, Penaeus aztecus, were taken at shore stations with the beam trawl (Table 3). Subadults were taken offshore with the shrimp trawl by June (Table 5). The same pattern was demonstrated for white shrimp, P. setiferus, starting later in the season (June). Larger white shrimp from previous spawnings were taken in April.

20. Postlarval fishes taken in the beam trawl were most abundant in March when 88 percent of all 1,505 specimens collected were Gulf menhaden, Brevoortia patronus (Table 3). This species accounted for 78 percent of all postlarval fishes caught with the beam trawl during the study. Of the 28 species collected with this gear, most were marine-estuarine, not estuarine only. Distribution of species and of numbers appeared random throughout the study with no obvious patterns. With an average tow covering 180 m^2 of bottom, (Baxter 1963) there was one postlarval fish collected per 2.1 m^2 of shore station area covered.

21. The bar seine captured the early juvenile stage of fishes. Highest catches with this gear occurred in March. There were 2,604 Atlantic croakers, Micropogon undulatus, in the March samples. This species was abundant at all four stations. All species are listed in descending order of abundance in Table 4. Each tow covered approximately 700 m^2; therefore, one fish was collected for every 2.8 m^2 of shore station seined.

22. To determine if relative differences in abundance and distribution of fishes and crustaceans occurred along the shoreline, data from the beam trawl (Table A3) and bar seine (Table A4) were combined. Numbers of fishes were evenly distributed between stations 1 (28 percent), 2 (29 percent), and 3 (30 percent). However, only 13 percent of the fishes were collected from station 4 at the eastern end. Brown and white shrimp were caught at all stations and were the most abundant invertebrates collected. No pattern was observed in the data other than the seasonal abundances of animals in the spring.

23. Shrimp trawl data were gathered from the four zones shown in Figure 2. As in the shoreline fish data, the only obvious difference is a seasonal one. Only 664 fish were captured in approximately 24,000 m^2 of bottom covered. This yields one fish per 36 m^2 of bottom. By weight, 1 g of fish was caught per 6.2 m^2 of bottom. Areal and temporal abundance and biomass data for trawl-caught nekton are presented in Table A7. Trawl-caught fish are listed in descending order of abundance and by month in Table 5, June was the month of greatest abundance when 40 percent of the trawled specimens were caught. Only 4 species of invertebrates were caught in the trawl (Table 5).

Benthos

24. Benthic data collected during the study are presented by sample period in Table 6. Detailed benthic data are presented by station, collection date, and sample replicate in Table A8. All benthic forms found fit into a grouping of eight taxa arranged by station and transect in Table 7. Table 8 compares benthos from transect 5, collected in October, with October collections from the four other transects.

25. Benthic abundance was found to be greater in the western portion of the site (transects 1 and 2). This was probably due to deposition of finer sediment observed in that area. Benthic abundance also varied between transects parallel to shore with fewer benthic animals collected along the shore than at middepth and offshore transects.

26. Of all benthic organisms identified, Polychaeta was the most abundant taxon comprising 40 percent of the benthic organisms collected. Sixteen species of polychaetes were taken representing 13 genera. Two species of polychaetes dominated the annelid population throughout the study. *Eteone heteropoda* comprised 34 percent of the number collected. *Parendalia fauveli*, the second most common species, accounted for 22 percent of all polychaetes taken. Although *Capitella capitata* is often a common species in estuarine studies, it made up only four percent of the Polychaeta collected. This species is usually found in finer textured bottoms or mud substrates.

27. Data of the most abundant polychaete, *E. heteropoda*, were examined for distribution within the area. Shoreline stations produced 55 percent of the total caught. No one station yielded more than 32 percent or less than 18 percent of those taken at shore stations. *E. heteropoda* occurred at all stations during this study. When transects perpendicular to shore were compared, transect 3 produced the greatest number of this species.

28. Upon examination of the distribution of all polychaetes collected, abundance was found to be greater in the western half of the field site. This distribution was similar to that observed for most benthic organisms collected; polychaetes were also more abundant at shore stations. Gilmore and Trent (1974) also found polychaetes most abundant at shore stations in a West Bay study. Station 1 in August and in October contained the most organisms by actual numbers, per square metre of bottom, and per litre of sediment. Both collections were also highest in organic content of the sediment for those two months. Transect 1 yielded 33 percent of all polychaetes; transect 2 contained 26 percent; transect 3, 24 percent; and transect 4 only 17 percent (Table 7).

In October, 17 percent of the polychaetes collected at the site were from the new transect 5.

29. In addition to polychaetes, other abundant benthic organisms included one species each of isopod, amphipod, and pelecypod. The isopod, Xenanthura brevitelson, was the most abundant species of all arthropod crustaceans obtained. Of the 542 arthropod crustaceans collected, this species represented 67 percent (364 specimens) and was collected on all sample dates and at all stations except station 8. Seventy percent of all X. brevitelson specimens were collected from the western transects (1 and 2). Transect 4 yielded only 8 percent of the total number collected.

30. Dominant amphipods were Haustoriidae, a family of burrowing amphipods well adapted to dynamic sand environments. Two and possibly more species of haustoriids occurred in the collections but identification below family could not be accomplished. Most amphipods occurred in April when 43 percent of the total number were taken. Distribution among transects was uniform, varying from 20 to 27 percent. Haustoriids were taken at every station in the area and occurred in every month.

31. The dominant pelecypod of the area (89 percent of the total number) was Periploma inequale, the unequal spoon clam, common to sandy bottom lagoons and inlet areas. Only four other pelecypod species were collected, including Mercenaria campechiensis and the long razor clam, Ensis minor. E. minor specimens, which were each 25 mm long, were the only pelecypods taken that measured more than 3 mm. Larger shells of this species were observed along the shore edge during the study but none were found alive or intact. It should be noted that no adult molluscs were collected and it is not known whether or not they complete their life cycle at this site. As with many other forms, pelecypods were in greatest abundance in the month of April. It is also interesting to note that although Mulinia lateralis and Macoma tenta are two species of pelecypods that are often dominant in benthic communities (Thorson, 1957), only eleven M. lateralis and three M. tenta were taken during this study.

32. The only other molluscs collected, other than pelecypods, were eight gastropod specimens represented by three species. The only specimen

larger than 2 mm was a moon snail, Polinices duplicatus. This specimen measured 25 mm, and was the only predatory species of mollusc taken. The other two species, Caecum pulchellum and Teinostoma biscaynense, are small and usually not abundant. Scarcity of the highly predatory P. duplicatus in the collections is probably due to the lack of prey in the area.

33. In addition to the benthic organisms described above, three forms of meiobenthos were also observed in the substrate: forams, ostracods, and nematodes. All three forms were abundant in March, and were most abundant in April, followed by a sharp decrease or total absence in numbers through the summer. A few nematodes and foraminifera were observed in the October samples. This is the expected pattern of seasonal abundance and agrees with studies such as that by Day et al. (1973). Because the sieve size of 0.5 mm is not really quantitative for these forms, no finer definition of meiofauna abundance was attempted.

Sediment analysis

34. Grams of organic matter per square metre of sediment surface are reported in Table 9 for every station sampled each month and by transects parallel and perpendicular to shore. Data for each replicate are presented in Table A9. Organic content of the area is considered to be low when compared with a general bay area. Sandy substrates in estuaries generally contain less organic matter than do finer grained substrates. The area does not have submerged vegetation, so there was, with only one exception, no detritus in samples. As discussed earlier, strong currents probably remove material of small particle size.

35. Grams of organic content per litre of sediment (g/ls) were also determined. All g/ls data gathered during the study from stations 1 through 15 are recorded in Table 10. The average g/ls for those stations was 0.1467. If station 1 data taken in August are not included, the average g/ls is 0.1323. This one extremely abundant sample yielded 68 percent of all organic matter for August and 13 percent of all organics combusted during this study. Station 1 in August also contained 44 percent of all polychaetes at that location during the study (Table A8a). It was the only time vegetative litter was observed at the sediment surface.

36. The amount of sedimentary organic content conforms to the seasonal pattern shown in abundance of organisms. A peak occurred in April and numbers decreased thereafter. Overall, organic content was highest in April (Tables 9 and 10) and lowest in October.

37. A chi-square test was performed to compare station differences using the hypothesis that there were no differences in organic matter between stations. All seasonal data were pooled for each station. At the 5 percent level with 14 degrees of freedom, no significant difference was detected. When transect data were examined, however, a trend was apparent that organic matter was greater at western transects 1 and 2.

Conclusions

38. Gilmore and Trent (1974) found slightly over 1200 polychaetes per square metre of open bay in West Bay samples. Samples from the proposed habitat site yielded an average of 358 polychaetes per square metre. With all macrobenthos combined, Gilmore and Trent collected an average of 1300 organisms per square metre. An average of only 864 macrobenthic organisms were collected per square metre at the habitat development site. In another study done in March, 1972*, 16 km east of this study site and along a similar shoreline, an average of 1105 macrobenthic animals were collected per square metre. In March 1975, this study yielded an average of 326 animals per square metre of bottom. In both of the other studies, polychaetes were more dense, the sites were further removed from influence of gulf waters, they were nearer *Spartina* marsh areas, and had not been subjected to recent deposition of dredged material. This could account for more uniform and productive environments in the other two studies.

39. Greatest organic content was found in April sampling (18.6 g/m^2 per station). At that time phytoplankton, zooplankton, and meiobenthic

*Unpublished data, National Marine Fisheries Service, Southeast Fisheries Center, Galveston Laboratory, Galveston, Texas.

populations were at their peak. Table 11, a summary of data by months and the overall 8-month study period combined, contains numerical abundance and biomass of the different parameters collected. It can be seen that postlarval and early juvenile fishes were not abundant any month except March. Zooplankters were lowest in August, but June was the month of least abundance of phytoplankton, benthic animals and organic content.

40. Ctenophores and coelenterates are not included in tabulated data but were observed throughout the study. When the pilot study was conducted in March, only a small number of *Beroe ovata* were observed in the water column. In April, *B. ovata* was still present and occasionally *Stomolophus meleagris* were found stranded along the shoreline. Numbers of *S. meleagris* increased on the shore by June and some were seen in August. By May, *Mnemiopsis mccradyi* was dense enough to cause clogging of the plankton net. *M. mccradyi* remained abundant through August. One of their predators, *Chrysaora quinquecirrha*, also became abundant in August.

41. Limited numbers of higher tropic level scavenger and predator species attest to the paucity of epibenthic life. The only epibenthic scavenger collected was the hermit crab, *Clibanarius vittatus*.

42. The closest oyster reef detected was over 6 km from the habitat development site. In *Spartina* and in oyster biotopes of East Bay, finer sediments, high animal abundance, and species of higher trophic level occur. Either type of assemblage could result if deposition of fine-textured sediment occurs and physical structures are placed in the study area to retain these finer sediments.

Recommendations

43. A project such as this should include the study of a relatively undisturbed area nearby and the study results should be used as an indication of the biological development of the study site.

44. Sampling should extend through one calendar year so as to encompass a complete life cycle of some organisms and determine temporary or seasonal utilization of the area by others. Diel sampling might

show nocturnal differences, especially in epibenthic forms.

45. A structure placed in an area for the purpose of increasing productivity should allow for some circulation of water. Circulation aids in preventing unstable situations such as phytoplankton blooms, allows freedom of movement by organisms that would use the area, and transports finer sediments for deposition. Strong scouring currents should, however, be restricted by structure design.

46. Structural configuration should simulate natural conditions. In this case, nearby Elmgrove Point and Marsh Point areas (U. S. C&GS Chart 1282) have desirable parameters. At both locations, bayous meander in a northwesterly direction from Bolivar Peninsula to the bay through marsh grass. The direction of the bayous and sand plume configuration indicates prevailing currents to the west. By applying desired design factors vegetative production might occur naturally in an altered area.

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Table 1

Diatom Species in Descending Order of Abundance and Percent of Total

March - June 1975*

Species	Date - Number/ml					
	March	April	May	June	Mean	Percent
Leptocylindrus minimus	1,102	6,700	15	210	2,007	35.5
Asterionella japonica	2,749	1,728	65	540	1,270	22.4
Navicula (1 to 5 spp.)	252	308	240	1,395	549	9.7
Skeletonema costatum	1,289	518	15	232	514	9.1
Thalassiosira (1 to 3 spp.)	154	1,198	210	202	450	8.0
Nitzschia (1 to 3 spp.)	111	392	555	285	336	5.9
Chaetoceros socialis		288		112	100	1.7
Coscinodiscus (sp.)	88	98	22	105	78	1.3
All Others	746	255	252	202	364	6.4
Total	6,491	11,485	1,374	3,283	5,658	100.0

*No phytoplankton were collected in August or October 1975.

Table 2

Major Groups of Zooplankton by Zones

March - October 1975

Groups	Zone - Number/m^3 I	II	III	IV	Mean	Std. Dev.	Percent
Barnacles	976.7	202.2	123.0	268.8	393	393.8	49.5
Copepods	611.7	254.6	183.9	397.4	362	188.7	45.6
Polychaetes	104.1	14.5	6.8	20.6	36	45.4	4.6
All Others	4.5	3.0	.5	1.2	2	1.6	0.3

Note: Zooplankton were not collected in Zones III and IV in August and October.

Table 3

Number of Postlarval Fishes and Crustaceans Taken at Shore Stations With the Beam-Trawl in Descending Order of Abundance

March - October 1975

Taxa	Date March 18	April 15	June 17	August 19	October 14	Total
Fish						
Gulf Menhaden (*Brevoortia patronus*)	1331	117				1448
Bay Anchovy (*Anchoa mitchilli*)	5		57	3	58	123
Atlantic Croaker (*Micropogon undulatus*)	70				2	72
Darter Goby (*Gobionellus boleosoma*)	32	2	9		3	46
Pinfish (*Lagodon rhomboides*)	20	12				32
Sheepshead (*Archosargus probatocephalus*)		25				25
Striped Mullet (*Mugil cephalus*)	18		1			19
Spot (*Leiostomus xanthurus*)	18					18
Southern Kingfish (*Menticirrhus americanus*)				10	4	14
Black Drum (*Pogonias cromis*)	4	6				10
Naked Goby (*Gobiosoma bosci*)			1	4	3	8
Ladyfish (*Elops saurus*)	2	4				6
Red Drum (*Sciaenops ocellata*)					6	6

(continued)

Table 3 (continued)

Taxa	Date: March 18	April 15	June 17	August 19	October 14	Total
Spotted Seatrout (*Cynoscion nebulosus*)				5		5
Inshore Lizzardfish (*Synodus foetens*)		1	2			3
Bay Whiff (*Citharichthys spilopterus*)	3					3
Speckled Worm Eel (*Myrophis punctatus*)	2					2
Longnose Killifish (*Fundulus similis*)			2			2
Tidewater Silverside (*Menidia beryllina*)			1		1	2
Atlantic Threadfin (*Polydactylus octonemus*)			2			2
Star Drum (*Stellifer lanceolatus*)					1	1
Atlantic Bumper (*Chloroscombrus chrysurus*)				1		1
Florida Pompano (*Trachinotus carolinus*)				1		1
Silver Perch (*Bairdiella chrysura*)			1			1
Southern Stargazer (*Astroscopus y-graecum*)		1				1
Chain Pipefish (*Syngnathus louisianae*)					1	1
Clown Goby (*Microgobius gulosus*)					1	1

(continued)

Table 3 (concluded)

Taxa	March 18	April 15	June 17	August 19	October 14	Total
	Date					
White Mullet (*Mugil curema*)			1			1
Totals	1505	168	77	24	80	1854
Crustaceans						
Brown Shrimp (*Penaeus aztecus*)	2122	138	40	73	2	2375
White Shrimp (*Penaeus setiferus*)	7		14	257	24	302
Seabob (*Xiphopeneus kroyeri*)				16	1	17
Blue Crab (*Callinectes sapidus*)				10		10
Hermit Crab (*Clibanarius vittatus*)				4		4
Totals	2129	138	54	360	27	2708

Table 4

Number of Juvenile Fishes and Crustaceans Taken at Shore Stations with the Bar Seine in Descending Order of Abundance

March - October 1975

Taxa	Date March 18	April 15	June 17	August 19	October 14	Total
Fish						
Atlantic Croaker (*Micropogon undulatus*)	2604	28	338		1	2971
White mullet (*Mugil curema*)			690	56		746
Spot (*Leiostomus xanthurus*)	253	3	198			454
Atlantic Threadfin (*Polydactylus octonemus*)		2	265			267
Bay Anchovy (*Anchoa mitchilli*)	137	2	37	57		233
Gulf Kingfish (*Menticirrhus littoralis*)			15	83	20	118
Sea Catfish (*Arius felis*)			77	39	1	117
Longnose Killifish (*Fundulus similis*)	34	13	15	45	2	109
Spanish Sardine (*Sardinella anchovia*)	77					77
Bay Whiff (*Citharichthys spilopterus*)	60	3				63
Sand Seatrout (*Cynoscion arenarius*)			4	2	44	50
Striped Mullet (*Mugil cephalus*)	4	1	21	7		33
Rough Silverside (*Membras martinica*)			5	24		29

(continued)

Table 4 (continued)

Taxa	March 18	April 15	June 17	August 19	October 14	Total
Florida Pompano (*Trachinotus carolinus*)			8	8		16
Crevalle Jack (*Caranx hippos*)			11	1		12
Gulf Killifish (*Lucania parva*)					9	9
Black Drum (*Pogonias cromis*)			5	2		7
Atlantic Bumper (*Chloroscombrus chrysurus*)					6	6
Atlantic Spadefish (*Chaetodipterus faber*)			5			5
Southern Flounder (*Paralichthys lethostigma*)	3	1				4
Southern Stargazer (*Astroscopus y-graecum*)		4				4
Leatherjacket (*Oligoplites saurus*)				2		2
Pinfish (*Lagodon rhomboides*)	2					2
Harvestfish (*Peprilus alepidotus*)				2		2
Sailfin Molly (*Poecilia latipinna*)					2	2
Silver Perch (*Bairdiella chrysura*)				1		1
Blackcheek Tonguefish (*Symphurus plagiusa*)			1			1
Least Puffer (*Sphoeroides parvus*)			1			1

(continued)

Table 4 (concluded)

Taxa	March 18	April 15	June 17	August 19	October 14	Total
	Date					
Scaled Sardine (*Harengula pensacolae*)				1		1
Tidewater Silverside (*Menidia beryllina*)	1					1
Red Drum (*Sciaenops ocellata*)			1			1
Totals	3175	57	1697	330	85	5344
Crustaceans						
White Shrimp (*Penaeus setiferus*)	16		1	344	4773	5134
Brown Shrimp (*Penaeus aztecus*)	371		371	3	196	941
Grass Shrimp (*Palaemonetes* sp.)	16	40	4		126	186
Seabob (*Xiphopeneus kroyeri*)				124	126	250
Blue Crab (*Callinectes sapidus*)	118	26	38	56		238
Hermit Crab (*Clibanarius vittatus*)				206		206
Totals	521	66	414	733	5221	6955

Table 5

Number of Trawl-Caught Fishes and Invertebrates by Months in Descending Order of Abundance, March - October 1975

Taxa	March 18	April 15	June 17	August 19	October 14	Total No.	Total Wt. g
	Date						
VERTEBRATES:							
Atlantic Croaker (*Micropogon undulatus*)	227	5	153	42		427	1677.4
Spot (*Leiostomus xanthurus*)	1	9	62	4	4	80	792.2
Sea Catfish (*Arius felis*)			10	63	7	80	610.0
Gulf Butterfish (*Peprilus burti*)	5		13			18	18.6
Bay Anchovy (*Anchoa mitchilli*)		8	2			10	30.6
Crevalle Jack (*Caranx hippos*)				7		7	31.4
Atlantic Thread Herring (*Opisthonema oglinum*)			6			6	20.2
Atlantic Threadfin (*Polydactylus octonemus*)			6			6	22.4
Pinfish (*Lagodon rhomboides*)			4			4	57.0
Harvestfish (*Peprilus alepidotus*)				4		4	7.2
Southern Stargazer (*Astroscopus y-graecum*)	2	1				3	3.4
Gulf Menhaden (*Brevoortia patronus*)			2		1	3	50.6
Sand Seatrout (*Cynoscion arenarius*)			3			3	32.2

(continued)

Table 5 (concluded)

Taxa	Date: March 18	April 15	June 17	August 19	October 14	Total No.	Total Wt. g.
Black Drum (*Pogonias cromis*)				3		3	108.0
Least Puffer (*Sphoeroides parvus*)	1		2			3	14.8
Inshore Lizzardfish (*Cynodus foetens*)			1			1	26.4
Red Drum (*Sciaenops ocellata*)				1		1	170.8
Striped Mullet (*Mugil cephalus*)			1			1	146.2
Atlantic Cutlassfish (*Trichiurus lepturus*)			1			1	15.4
Bighead Searobin (*Prionotus tribulus*)	1					1	1.0
Florida Pompano (*Trachinotus carolinus*)			1			1	3.6
Southern Kingfish (*Menticirrhus americanus*)				1		1	47.4
Totals	237	23	267	125	12	664	3886.8
INVERTEBRATES:							
Brown Shrimp (*Penaeus aztecus*)	3		264		1	268	621.3
White Shrimp (*Penaeus setiferus*)	116	3			55	174	513.7
Blue Crab (*Callinectes sapidus*)	9		4	2		15	2601.0
Squid (*Loligo* sp.)				2	5	7	49.0
Totals	128	3	268	4	61	464	3785.0

Table 6

Number of Benthic Invertebrates Arranged by Collection Dates and Species,*

March-October 1975

Taxa	Date					Total
	March	April	June	August	October	Number
RHYNCOCOELA						
Tubulanus pellucidus	2	2	2	3	4	13
POLYCHAETA						
Eteone heteropoda	27	55	3	32	47	164
Scoloplos foliosus			5	7	74	86
S. fragilis			1			1
Parendalia fauveli	7	5	3	37	58	110
Aricidae fragilis			9	22	21	52
Heteromastus filiformis			5	21	6	32
Nereis succinea	2	2		2		6
N. occidentalis			1			1
Owenia fusiformis		1				1
Pseudeurythoe ambiqua	1	2		1	4	8
Glycindes solitaria		1		2		3
Nephtys sp.					1	1
Nephtys magellanica		1				1
Capitella capitata			1		19	20
Mediomastus californiensis			2			2
Diopatra cuprea				1		1
ORBINIIDAE			6			6
TEREBELLIDAE			1			1
UNKNOWN (Young)			3			3
MOLLUSCA						
GASTROPODA						
Teinostoma biscaynense	2	1				3
Polinices duplicatus	2			1	1	4
Caecum pulchellum				1		1
PELECYPODA						
Periploma inequale	40	80	8	1	25	154
Mulinia lateralis	2	1			8	11
Ensis minor		2				2
Macoma tenta			1	2		3
Mercenaria campechiensis		1				1
Unidentified					2	2

(continued)

Table 6 (concluded)

Taxa	March	April	June	August	October	Total Number
	Date					
CUMACEA		1		1		2
ISOPODA						
Xenanthura brevitelson	68	136	19	68	73	364
HAUSTORIIDAE	49	73	19	5	25	171
BRACHYURA						
Pinnixa cristata		1			4	5

*Unidentified fragments not included.

Table 7

Macrobenthic Organisms per Litre of Sediment According to Taxa, Stations, and Transects, March-October 1975

	Organism-Number/litre of Sediment								All Benthos
	Polychaetes	Nemerteans	Amphipods	Isopods	Pelecypods	Gastropods	Brachyurans	Cumacea	per Litre
Shore Stations									
1	14.0	-	1.4	4.7	0.1	-	-	-	20.2
2	6.0	0.1	0.8	1.7	0.1	-	-	-	8.7
3	5.0	-	2.3	2.0	0.5	-	-	0.1	9.9
4	4.3	-	1.2	2.1	0.1	-	-	-	7.7
Middepth Stations									
5	4.5	0.1	2.4	7.9	1.5	0.1	-	-	16.5
6	4.5	0.1	3.0	13.9	3.8	0.1	0.1	-	25.5
7	3.4	0.2	3.0	6.8	1.8	-	-	0.1	15.3
8	1.6	0.1	1.9	-	1.4	-	-	-	5.0
Offshore Stations									
9	4.0	0.1	1.8	1.5	3.9	0.3	-	-	11.6
10	6.2	0.3	2.1	2.6	4.1	0.3	-	-	15.6
11	7.1	0.5	1.3	3.2	1.8	0.2	-	-	14.1
12	5.6	0.3	0.8	1.6	1.6	-	0.4	-	10.7
Transects perpendicular to shore									
1	7.2	0.1	1.9	4.8	1.9	0.1			16.0
2	5.6	0.2	1.8	5.8	2.5	0.1			16.0
3	5.1	0.2	2.2	4.0	1.3	0.1			12.9
4	3.7	0.1	1.3	1.2	1.2	-			7.5
Transects parallel to shore									
Shore	7.3	0.1	1.4	2.6	0.2	-			11.6
Middepth	3.5	0.1	2.6	7.8	2.1	0.1			16.2
Offshore	5.7	0.2	1.5	2.1	2.8	0.2			12.5
All data $\bar{x}$	5.5	0.1	1.7	3.7	1.7	0.1			12.8

...tre of Sediment

October 1975

	Transect					
	1	2	3	4	5	
...aetes	10.6	7.8	7.5	5.1	6.4	[illegible]
Isopod	4.3	2.5	3.6	1.4	0.8	[illegible]
Amphipod	1.0	1.2	0.6	0.6	0.6	[illegible]
Pelecypod	0.5	1.2	0.6	0.8	0.9	(
Gastropod	0.2	-	-	-	-	< 0.
Nemertea	-	0.2	0.4	0.2	-	0.2
Brachyura	-	-	-	0.4	0.1	0.1
All Benthos*	16.6	12.9	12.7	8.5	8.8	11.9

*Total numbers of organisms divided by total litres of sediment.

Table 9

Grams of Organic Matter per Square Metre Sediment Surface, by Stations, Transects, and Months,* March-October 1975

	March	April	June	August	October	All Months Combined
			Transects 1-5			
Station						
1	12.8224	28.2239	11.7416	97.0807	13.1108	32.5959
2	10.0151	9.3649	13.3778	6.5231	6.2820	9.1126
3	3.7416	18.5963	7.0656	4.0086	7.6081	8.2040
4	8.7616	5.3390	1.5285	6.9709	5.3003	5.5801
5	7.3541	29.3304	5.1152	8.6760	2.6008	10.6153
6	25.9892	5.6138	2.0409	4.3789	1.9720	7.9990
7	2.2807	4.9924	3.0743	4.8439	5.1238	4.0631
8	20.4792	34.1485	3.8579	4.1679	2.1787	12.9664
9	5.8256	2.9322	2.2130	3.2292	2.0366	3.2474
10	4.7147	51.1922	2.8793	5.3649	2.9451	13.4194
11	2.9386	27.8364	5.3261	2.8159	1.9548	8.1744
12	3.3369	6.1442	5.9419	8.3918	4.8008	5.7232
13	-	-	-	-	2.7642	2.8642
14	-	-	-	-	3.7115	3.7115
15	-	-	-	-	9.5500	9.5500
Transects perpendicular to shore						
1	8.6673	20.1621	6.3566	36.3286	5.9160	15.4861
2	13.5730	22.0569	6.0993	5.4223	3.7330	10.1769
3	2.9869	17.1417	5.1553	3.8894	4.8955	6.8138
4	10.8592	15.2105	3.7761	6.5102	4.0933	8.0898
5	-	-	-	-	5.3419	5.3419
Transects parallel to shore						
Shoreline	8.8351	15.3810	8.4283	28.6458	7.0131	13.6607
Middepth	14.0258	18.5212	3.5220	5.5166	3.1174	8.9406
Offshore	4.2039	22.0262	4.0900	4.9504	4.2575	7.9056
All Data	9.0216	18.6428	5.3467	13.0376	4.7959	10.1689

*Determined by ash-free dry-weight procedure.

Table 10

Grams of Organic Matter per Litre of Sediment

Arranged by Station, Transect, and Month,*

March-October 1975

	March	April	June	August	October	All Months Combined
			Transects 1-5			
Station						
1	0.2041	0.4708	0.3084	1.3664	0.1581	0.5015
2	0.1069	0.1529	0.2235	0.0681	0.0522	0.1207
3	0.0920	0.3255	0.0949	0.0521	0.0637	0.1256
4	0.1244	0.1145	0.0352	0.0683	0.0660	0.0817
5	0.1334	0.4883	0.0834	0.0716	0.0331	0.1620
6	0.4679	0.0816	0.0456	0.0414	0.0269	0.1327
7	0.0477	0.4752	0.0816	0.0762	0.0558	0.1473
8	0.3980	0.6848	0.0864	0.0308	0.0269	0.2454
9	0.1294	0.0717	0.0528	0.0281	0.0200	0.0604
10	0.0904	0.9339	0.0615	0.0625	0.0266	0.2350
11	0.0637	0.4667	0.0932	0.0475	0.0302	0.1403
12	0.0677	0.1005	0.1221	0.0889	0.0520	0.0862
13	-	-	-	-	0.0347	0.0347
14	-	-	-	-	0.0374	0.0374
15	-	-	-	-	0.0899	0.0899
Transects perpendicular to shore						
1	0.1556	0.3436	0.1482	0.4887	0.0704	0.2413
2	0.2217	0.3895	0.1102	0.0573	0.0352	0.1628
3	0.0678	0.4225	0.0899	0.0586	0.0499	0.1377
4	0.1967	0.2999	0.0812	0.0627	0.0483	0.1378
5	-	-	-	-	0.0540	0.0540
Transects parallel to shore						
Shore-line	0.1319	0.2659	0.1655	0.3887	0.0749	0.2054
Mid-depth	0.2618	0.4325	0.0743	0.0550	0.0360	0.1719
Off-shore	0.0878	0.3932	0.0824	0.0568	0.0437	0.1328
All Data	0.1605	0.3639	0.1074	0.1668	0.0516	0.1467

*Determined by ash-free dry-weight procedure.

Table 11

Seasonal Distribution of Environmental Parameters

March-October 1975

	March	April	June	August	October	All Months Combined
Organics g/m^2	9	19	5	13	5	10
Benthos Organisms/m^2	804	1363	326	775	1055	864
Phytoplankton (Diatoms/ml)	6530	11482	3285	-	-	-
Zooplankton per m^3 (Zones I and II)	2563	3762	297	58	416	1419
Postlarval Fishes per 1,000 m^2	2090	233	107	36	86	644
Early Juvenile Fishes per 1,000 m^2	1142	23	607	119	24	366
Juvenile Fishes per 1,000 m^2	19	2	28	13	1	13

- = No data.

APPENDIX A'

Sampling Collection Data From

The Bolivar Peninsula Site

AD-A063 780 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS F/G 13/3
HABITAT DEVELOPMENT FIELD INVESTIGATIONS, BOLIVAR PENINSULA MAR--ETC(U)
AUG 78 H H ALLEN, E J CLAIRAIN, R J DIAZ

UNCLASSIFIED WES-TR-D-78-15 NL

4 OF 4
AD
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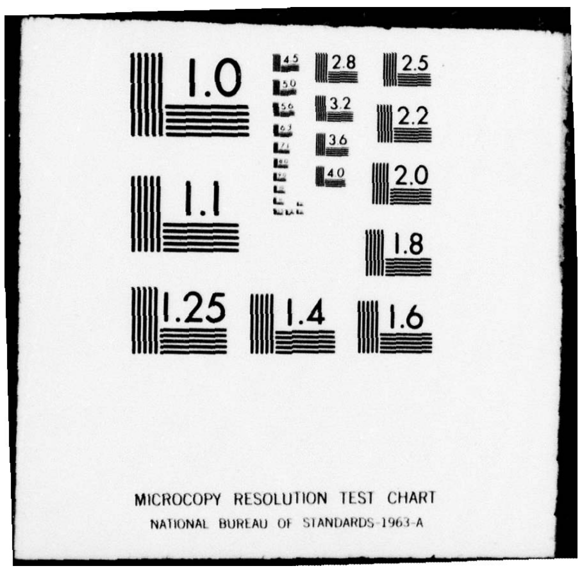
1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Table A1

Types of Collections Taken by

Dates, Zones, and Stations

1975	Zone: Intertidal I	Zone: Open Water II	Zone: West Intertidal III	Zone: East Intertidal IV	Station: Shoreline 1	2	3	4	13	Outer-Intertidal 5	6	7	8	14	Open Water 9	10	11	12	15
March 18	P	P	P	P															
	Z	Z	Z	Z	M	M	M	M	M										
	N	N	N	N	B	B	B	B		B	B	B	B		B	B	B	B	
April 15	P	P	P	P						B	B	B	B		B	B	B	B	
	Z	Z	Z	Z	M	M	M	M											
	N	N	N	N	B	B	B	B											
May 13	P	P	P	P															
	Z	Z	Z	Z															
June 18	P	P	P	P															
	Z	Z	Z	Z	M	M	M	M		B	B	B	B		B	B	B	B	
	N	N	N	N	B	B	B	B											
August 19	Z	Z																	
	N	N	N	N															
					M	M	M	M		B	B	B	B		B	B	B	B	
					B	B	B	B											
October 14	Z	Z			B	B	B	B	B										
	N	N	N	N						B	B	B	B	B	B	B	B	B	B
					M	M	M	M	M										

Key: P - Phytoplankton
Z - Zooplankton
N - Nekton
M - Meroplankton postlarval fish
B - Benthos

Table A2

Environmental Data Collected on Each Sample Date

Date and Location 1975	Temperature (°C)		Salinities (Parts per Thousand) Transects and Zones					Remarks
	Air	Water	1 (I)	2 (II)	3 (III)	4 (IV)	5	
March 18								
Shore	18-20	17-20	19	19	19	19		Wind 10 Knots per hour, NW.
Offshore	18-20	18-18	20	20	20	20		Tide app. 0.3 m
April 15								
Shore	20-23	17-18	15	15	15	14		Wind 8 Knots per hour, E.
Offshore		14-16	12	12	12	12		Tide app. 0.1 m
May 13								
Shore	29-29	29-29	10	10	10	10		Wind 10 Knots per hour, SE.
Offshore		29-29	10	10	10	10		
June 17								
Shore		28-31	12	12	12	12		Wind 16 Knots per hour, SSE.
Offshore	28-31	28-29	12	12	14	12		Tide 0.5 m
August 19								
Shore	28-34	28-32	19	20	19	19		Wind calm, S.
Offshore	28-35	28-30	20		20	17		Tide 0.1 m
October 14								
Shore	28	26-28	24	24	24	22	20	Wind 10 Knots per hour, SE and
Offshore	28	26	24	25	25	24		15 Knots per hour, NW. 0.2 m

Table A3

Abundance and Range of Lengths (mm) of Postlarval Fishes and Crustaceans

Taken at Shore Stations with the Beam-Trawl,

March - October 1975

Species	Date of Collection																				Total
	March 18				April 14				June 17				August 19				October 14				
	Stations																				
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	13	
Gulf Menhaden	296	40	930	65	48	12	6	51														1448
Brevoortia patronus	19/	18/	19/	18/	18/	16/	18/	18/														16/
	22	22	29	21	22	21	20	20														22
Bay Anchovy	1	1	3						7	10	34	6				3	2	15	23	3	15	123
Anchoa mitchilli	/	/	28/						22/	19/	6/	20/				42/	14/	15/	14/	21/	11/	6/
	48	43	45						44	27	43	26				45	22	19	21	22	22	48
Atlantic Croaker	17	10	20	23															1	1		72
Micropogon undulatus	23/	23/	19/	23/															/	/		6/
	43	36	33	37															6	8		43
Darter Goby	6	11	14	1		2				1	4	4						1	1		1	46
Gobionellus	9.8/	9.2/	9.8/	/		10/				/	8.2/	8.7/						/	/		/	8.2/
boleosoma	10	10	11	11		14				8.6	8.9	9.9						13	9.2		8.9	11
Pinfish	4	3	13		2	3	2	5														32
Lagodon rhomboides	13/	13/	12/		13/	12/	12/	12/														12/
	14	14	14		14	13	12	13														14
Sheepshead					6	11	2	6														25
Archosargus					8.0/	8.6/	8.4/	8.1/														8.0/
probatocephalus					9.3	9.5	8.6	8.4														9.5
Striped Mullet	1	2	15									1										19
Mugil cephalus	/	19/	17/									/										12/
	12	22	24									93										93
Spot	6	2	9	1																		18
Leiostomus	11/	11/	10/	/																		10/
(xanthurus	13	12	14	13																		14

(continued)

Table A3 (continued)

Species	March 18				April 15				June 17				August 19				October 14					
	Stations																					
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	13	Total
Southern Kingfish *Menticirrhus americanus*													3 20/ 33	4 14/ 43	1 / 22	2 4.2/ 4.3			3 25/ 28	1 / 20		14 4.2/ 43
Black Drum *Pogonias cromis*	1 / 5.9	1 / 5.7	2 5.5/ 5.8		2 5.1/ 5.5	1 / 5.3		3 5.1/ 5.8														10 5.1/ 5.9
Naked Goby *Gobiosoma bosci*											1 / 8.3				3 7.3/ 7.6	1 / 6.6	1 / 7.4	1 / 7.0		1 / 8.0		8 6.6/
Ladyfish *Elops saurus*		1 / 38	1 / 33		3 31/ 43	1 / 35																6 31/ 43
Red Drum *Sciaenops ocellata*																			3 5.8/ 8.3		3 7.3/ 7.6	6 5.8/ 8.3
Spotted Seatrout *Cynoscion nebulosus*													1 / 4.8	1 / 5.3	3 4.1/ 5.5							5 4.1/ 5.5
Inshore Lizardfish *Synodus foetens*					1 / 41				1 / 39	1 / 37												3 37/ 41
Bay Whiff *Citharichthys spilopterus*	1 / 32			2 9.9/ 10																		2 9.9/ 32
Speckled Worm Eel *Myrophis punctatus*			2 46/ 52																			2 46/ 52
Longnose Killifish *Fundulus similis*										1 / 34	1 / 30											2 30/ 34

(continued)

Table A3 (continued)

	Date of Collection																					
	March 1[illegible]				April 15				June 17				August 19				October 14					
	Stations																					
Species	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	13	Total
Tidewater Silverside <u>Menidia beryllina</u>											1/27							1/29				2/27/
Atlantic Threadfin <u>Polydactylus octonemus</u>									2/49/53													2/49/53
Star Drum <u>Stellifer lanceolatus</u>																	1/5.0					1/5.0
Atlantic bumper <u>Chloroscombrus chrysurus</u>																	1/9.3					1/9.3
Florida Pompano <u>Trachinotus carolinus</u>																1/13						1/13
Silver Perch <u>Baridiella chrysura</u>									1/4.2													1/4.2
Southern Stargazer <u>Astroscopus y-graecum</u>					1/38																	1/38
Chain Pipefish <u>Syngnathus louisianae</u>																		1/104				1/104
Clown Goby <u>Microgobius gulosus</u>																			1/8.1			1/8.1
White Mullet <u>Mugil curema</u>									1/32													1/32

(continued)

Table A3 (concluded)

Species	March 18				April 15				June 17				August 19				October 14					Total
	Stations																					
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	13	
Brown Shrimp	482	240	1265	135	75	34	17	12	11	10	8	11	23	26	18	6					6	2375
<u>Penaeus</u> <u>aztecus</u>	11/	11/	11/	11/	10/	10/	11/	11/	44/	25/	44/	/	8/	9/	19/	8/						8/
	14	13.5	17	14	17	13	13	13	75	71	80	55	9	90	95	20						95
White Shrimp	1		5	1					4		1	9	21	82	93	61	11		1	7	5	302
<u>Penaeus</u> <u>setiferus</u>	/		40/	/									5/	5/	5/	5/	23/					5/
	45		50	55									7	45	65	33	45					65
Seabob													12	2	1	1	1					17
<u>Xiphopeneus</u>													10/	9/	/	/	/					9/
<u>kroyeri</u>													34	15	12	12	33					34
Blue Crab													4		3	3						10
<u>Callinectes</u> <u>sapidus</u>													11/		12/	9.1/						9.1/
													24		24	23						24
Hermit Crab														2		2						4
<u>Clibanarius</u> vittatus																						
Total	483	240	1270	136	75	34	17	12	15	10	9	20	60	112	115	73	12	0	1	7	7	2708

Table A4

Abundance and Range of Lengths(mm) of Juvenile Fishes and Crustaceans

Taken at Shore Stations with the Bar Seine

March - October 1975

Species	March 18				April 15				June 17				August 19				October 14	Total
	Stations																	
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	all stations	
Atalntic Croaker	996	697	360	551	10	18			72	192	68	6					1	2971
Micropogon	20/	28/	25/	25/	35/	40/			41/	40/	47/	53/						20/
undulatus	75	66	70	65	50	50			82	88	75	75						88
White Mullet									85	494	104	7	37	13		6		746
Mugil curema									35/	26/	26/	33/	42/	44/		41/		26/
									54	59	39	47	76	69		71		76
Spot	14	205	16	18		3			55	39	69	35						454
Leiostomus	37/	27/	13/	35/		/			44/	40/	45/	38/						13/
xanthurus	62	69	54	64		40			75	69	70	72						75
Atlantic Threadfin					2				41	76	134	14						267
Polydactylus					40/				46/	45/	44/	45/						40/
octonemus					50				55	54	55	59						59
Bay Anchovy	38	9	73	17	2				6	12	18	1	11	7	35	4		233
Anchoa mitchilli	41/	45/	41/	38/	45/				37/	38/	26/	/	29/	32/	31/	20/		20/
	52	49	57	51	50				46	53	47	44	44	41	39	38		57
Gulf Kingfish									3	6	6		27	;6	38	2	20	118
Menticirrhus littoralis									37/	32/	25/		24/	26/	25/	29/		24/
									48	42	108		56	54	56	37		108
Sea Catfish									17	40	8	12	9	2	28		1	117
Arius felis									40/	43/	77/	78/	41/	38/	41/			38/
									102	232	94	100	55	46	48			
Longnose Killifish	3	1	29	1	6	2	5		4	3	8		1	16	2	26	2	109
Fundulus similis	40/	/	29/	/	40/	40/	40/		36/	34/	27/		/	38/	36/	30/		27/
	61	61	68	65	60	45	55		47	43	55		40	42	39	43		68

(continued)

Table A4 (continued)

Species	March 18				April 15				June 17				August 19				October 14	Total
	Date of Collection																	
	Stations																	
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	all stations	
Spanish Sardine Sardinella anchovia	76 19/ 23			1 / 22														77 19/ 23
Bay Whiff Citharichthys spilopterus	14 25/ 39	26 23/ 55	5 21/ 28	15 27/ 48	1 / 35	2 / 45												63 21 55
Sand Seatrout Cynoscion arenarius									1 / 48	1 / 38	1 / 61	1 / 50	2 27/ 31				44	50 27/ 61
Striped Mullet Mugil cephalus			4 19/ 24				1 / 30		9 103/ 141	4 70/ 136		3 71/ 122	1 / 80	6 75/ 99				33 19/ 141
Rough Silverside Membras martinica									1 / 73	3 24/ 73		1 / 63		8 30/ 44		16 30/ 44		29 24/ 73
Florida Pompano Trachinotus carolinus									4 26/ 37	2 40/ 41	2 35/ 37		1 / 44	1 / 42	1 / 33	5 35/ 50		16 26/ 50
Crevalle Jack Caranx hippos									4 27/ 34		7 29/ 32			1 / 37				12 27/ 37
Rainwater Killifish Lucania parva																	9	9
Black Drum Pogonias cromis									1 / 28	2 29/ 36	1 / 32	1 / 34		2 44/ 62				7 28/ 62
Atalntic Bumper Chloroscombrus chrysurus																	6	6

(continued)

Table A4 (continued)

Species	March 18				April 15				June 17				August 19				October 14	Total
	Stations																	
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	all stations	
Atlantic Spadefish Chaetodipterus faber									2 25/ 26	2 14/ 21		1 / 22						5 14/ 26
Southern Flounder Paralichthys lethodtigma	3 35/ 39						1 / 70											4 35/ 70
Southern Stargazer Astroscopus y-graecum					3 30/ 35	1 / 30												1 30/ 35
Leather jacket Oligoplites saurus													1 / 56	1 / 46				2 46/ 56
Pinfish Lagodon rhomboides	2 13/ 14																	2 13/ 14
Harvest fish Peprilus alepidotus															2 18/ 22			2 18/ 22
Sailfin Molly Poecilia latipinna																	2	2
Silver Perch Bairdiella chrysura													1 / 55					1 / 55
Black Cheek Tonguefish Symphurus plagiusa										1 / 47								1 / 47
Least Puffer Sphoeroides parvus										1 / 28								1 / 28

(Continued)

Table A4 (concluded)

Species	March 18 1	March 18 2	March 18 3	March 18 4	April 15 1	April 15 2	April 15 3	April 15 4	June 17 1	June 17 2	June 17 3	June 17 4	August 19 1	August 19 2	August 19 3	August 19 4	October 14 all stations	Total
Scaled Sardine _Harengula pensacolae_													1 / 35					1 / 35
Tidewater Silverside _Menidia beryllina_				1 / 60														1 / 60
Red Drum _Sciaenops ocellata_									1 / 183									1 / 183
Total	1146	938	487	604	24	26	7	0	306	878	426	87	92	73	106	59	85	5344
White Shrimp _Penaeus setiferus_			13 44/ 83	3 45/ 55							1 / 124		310 28/ 80	24 34/ 72	10 40/ 67		4773	5134 28/ 124
Brown Shrimp _Penaeus aztecus_									106 38/ 84	152 31/ 90	90 40/ 92	23 41/ 78	1 / 59		2 67/ 78		196	570 31/ 92
Seabob _Xiphopeneus kroyeri_													124 25/ 87				126	250 25/ 87
Blue Crab _Callinectes sapidus_	32 17/ 69	21 16/ 75	24 10/ 70	41 16/ 88	9 25/ 90	12 25/ 70	5 25/ 70		10 14/ 137	17 15/ 47	10 19/ 162	1 / 19	24 16/ 102	21 16/ 120	7 18/ 38	4 18/ 25		238 10/ 162
Hermit Crab _Clibanarius vittatus_													73 / ?	73 / ?	33 / ?	27 / ?		206 / ?
Grass Shrimp _Palaemonetes_ sp.	1 / 28	9 28/ 36	6 22/ 34		12 30/ 40	220 35/ 40	5 35/ 40	3 30/ 35	2 29/ 30	1 / 32	1 / 29						126	186 22/ 40
Total	33	30	43	44	21	32	10	3	118	170	102	24	532	118	52	31	5221	6584

Table A5

Counts of Phytoplankton, March-June, 1975

(Numbers per Millilitre)*

Organism	Zones I	II	III	IV
a. March 18, 1975				
Diatoms				
Asterionella japonica**	3205	1350	3680	2760
Leptocylindrus minimus	680	1055	2145	530
Skeletonema costatum	660	870	1135	2490
Navicula spp.	445	185	190	190
Rhizosolenia fragilissima	345	110	60	230
Chaetoceros similis	165			130
Amphora ostrearia	140			
Surirella smithii	140		60	
Thalassiosira rotula	140	60	320	120
Thalassionema nitzchioides	120	60		
Coscinodiscus sp.	60+	130	60	100
Biddulphia mobiliensis	60			
Rhizosolena robusta	60			
Nitzchia closterium	60	60	130	
Podosira stelliger	60			
Ditylum brightwelli	60	120	100	135
Licmophora jurgensii	60			
Pleurosigma aestaurii	60			
Cyclotella sp.		100		290
Hantzschia virgata		60		
Rhizosolenia hebeta		60		
Nitzschia sp.			100	60
Gyrosigma sp.			60	
Amphora sp.		110		
Thalassiosira nordenskioldii				130
Subtotal	6520	4330	8040	7165
Dinoflagellates				
Peridinium trochoideum	60			
Exuviella cassubica	60	110		
Dinoflagellate cyst	60			
Prorocentrum micans		60		
Lunate cyst		180		180
Subtotal	180	350	0	180
Green Algae				
Biflagellated zoospore	60			
Carteria sp.	60			
Stichococcus sp.	60			
Unidentified coccoid			430	
Subtotal	180	0	430	0

(continued)

Table A5 (continued)

Organism	Zones I	II	III	IV
	b. April 15, 1975			
Diatoms				
*Leptocylindrus minimus***	5240	7850	6920	6790
Asterionella japonica	2690	1060	1450	1710
Thalassiosira rotula	580	60	1410	1160
Thalassiosira pseudonana	410	620	340	210
Nitzschia closterium	400	260	140	140
Skeletonema costatum	230	250	930	660
Navicula spp.	230	310	480	210
Chaetoceros socialis	230		440	480
Melosira suleata	160	60		60
Coscinodiscus sp.	60	60	60	210
Nitzschia sp.	60	210		360
Pleurosigma sp.	60			
Melosira sp.		60		
Rhizosolenia sp.		60		
Amphora sp.			120	
Hemiaulus hauckii			60	
Ditylum brightwelli			60	60
Thalassionema nitzschioides			60	60
Fragilaria sp.				140
Cyclotella sp.				120
Subtotal	10350	10860	12470	12370
Dinoflagellates				
Exuviella (*cassubica*?)		60		
Peridinium trochoideum		60		
Exuviella (*baltica*?)			140	
Cyst				60
Subtotal	0	120	140	60
Green Algae				
Carteria sp.	60	60	60	
Dunaliella sp.	60	60		60
Subtotal	120	120	60	60
Blue-Green Algae				
Oscillatoria sp.	60			
Chroococcus sp.		60		
Spirulina (filament)		60		
Subtotal	60	120	0	0

(continued)

Table A5 (continued)

Organism	Zone I	II	III	IV
	c. May 13, 1975			
Diatoms				
Nitzschia lanceolata**	510	240	270	210
Chaetoceros gracile	120	30	330	
Navicula spp.	150	180	510	120
Thalassiosira pseudonana	120	120	420	180
Nitzschia closterium[2]	120	150	510	210
Leptocylindrus minimus	120		110	30
Gyrosigma hippocampus	30	30	30	110
Skeletonema costatum	30	30		
Hantzschia sp.		120	120	30
Coscinodiscus sp.		30	30	30
Bacteriastrum sp.		30	30	
Subtotal	1200	960	2360	920
Dinoflagellates				
Gymnodinium sp.	30			
Prorocentrum micans	30	110		
Subtotal	60	110	0	0
Euglenoids				
Eutreptia sp.		30		30
Subtotal	0	30	0	30
Green Algae				
Platymonas sp.	30	30	110	30
Subtotal	30	30	110	30
Blue-Green Algae				
Gleocapsa sp.	240	210	540	360
Oscillatoria sp.	540		1470	420
Subtotal	780	210	2010	780

(continued)

Table A5 (concluded)

Organisms	Zones I	II	III	IV
d. June 17, 1975				
Diatoms				
Navicula spp.	1440	1710	1290	1140
Asterionella japonica[2]	540	360	90	1170
Leptocylindrus minimus	360	180	150	150
Chaetoceros socialis	300		120	30
Nitzschia closterium	210	240	180	210
Skeletonema costatum[2]	210	300	120	300
Coscinodiscus sp.	210	210	90	120
Thalassiosira rotula	210	330		270
Nitzschia lanceolata	120	120	90	90
Licmorpha flabellata	60			
Thalassionema nitzschioides	60		120	30
Rhizosolenia sp.	60		30	
Cyclotella sp.		240	120	90
Subtotal	3780	3690	2400	3600
Dinoflagellates				
Prorocentrum micans	90			
Dinoflagellate cyst	30	60	30	
Exuviella sp.			60	
Subtotal	120	60	90	0
Green Algae				
Dunaliella sp.		90	90	60
Subtotal	0	90	90	60
Euglenoids				
Eutreptia pertyi		60	30	30
Subtotal	0	60	30	30
Blue-Green Algae				
Oscillatoria sp.	2970	930	780	660
Chroococcus sp.	510	210	90	390
Gloeocapsa	270	180		60
Subtotal	3750	1320	870	1110
TOTAL	27,130	22,460	29,100	26,395

*Counts were made with a Palmer-Maloney counting cell and a phase-contrast microscope. The number shown represents the counts of seven or fourteen preparations calculated to give the number per millilitre. Seven preparations represent a total volume of 0.1 millilitre.

**Many of the organisms observed occurred in various colonial forms. For such individuals the individual cells and not the colony are counted.

+Counts that are less than 100 per millilitre are based on the observation of one specimen of that species in the total number of preparations counted.

Table A6

Replicate Zooplankton Samples by Zone, Date, and Taxa

(Organisms per m^3 Water)

Taxa	March 18 Replicate A	March 18 Replicate B	April 15 Replicate A	April 15 Replicate B	May 13 Replicate A	May 13 Replicate B	June 17 Replicate A	June 17 Replicate B	August 19 Replicate A	August 19 Replicate B	October 14 Replicate A	October 14 Replicate B
a. ZONE I												
Copepod	557.5	2194.4	1348.2	1876.6	4.0	7.5	45.6	655.0	23.0	25.5	159.0	444.3
Barnacle	823.0	4870.5	2340.4	3458.0	5.3	4.5	12.5	108.7	34.6	43.4	3.3	16.5
Polychaete	212.4	909.9	17.9	22.7	0.7		0.9	3.1	2.1	1.2	8.6	69.1
Mysidacean	79.6											
Crustacean Egg	26.5											
Nematode		160.6										
Crab Zoea			15.7	20.1				3.1	2.1			
Palaemonid							0.9	1.6				
Callianassid							0.9	1.6				
Isopoda								1.6	6.3	1.2		
Urochordate											10.5	95.4

(continued)

Table A6 (continued)

Taxa	March 18 Replicate A	March 18 Replicate B	April 15 Replicate A	April 15 Replicate B	May 13 Replicate A	May 13 Replicate B	June 17 Replicate A	June 17 Replicate B	August 19 Replicate A	August 19 Replicate B	October 14 Replicate A	October 14 Replicate B
b. ZONE II												
Copepod	174.4	33.0	1112.6	780.6	101.1	66.4	132.3	166.3	43.9	22.8	234.5	187.7
Barnacle	69.8	66.0	1092.4	1052.5	23.4	24.5	21.9	26.3	9.0	6.3	8.91	24.8
Polychaete	58.1	16.5		8.0	3.2	2.0	1.2	1.2		0.7	35.6	46.9
Nematode				1.1								
Crab Zoea			8.6	9.1	1.6	0.6		1.2	9.0	1.7	3.0	2.8
Palaemonid					0.4	0.9						
Callianassid							2.3					
Isopoda						0.3		1.2	0.3			
Anchovy Larva				1.1								
Brown Shrimp						0.6						
Urochordate											175.2	138.0
Crustacean Zoea					0.4							
Anchovy					0.8							

(continued)

Table A6 (continued)

Taxa	March 18 Replicate A	March 18 Replicate B	April 15 Replicate A	April 15 Replicate B	May 13 Replicate A	May 13 Replicate B	June 17 Replicate A	June 17 Replicate B	August 19 Replicate A	August 19 Replicate B	October 14 Replicate A	October 14 Replicate B
c. ZONE III												
Copepod	141.7	35.9	152.1	78.2	119.1	79.5	268.6	596.1				
Barnacle	57.6	77.8	430.3	348.1	41.8	4.7	5.3	18.8				
Polychaete	35.4	12.0	4.0	2.5	0.7							
Crab Zoea					4.2	1.2		4.9				
Palaemonetes								1.8				
Brown Shrimp							1.3	1.4				
Medusae	4.4											
Crab Megalops		3.0										
Anchovy					0.7							
White Shrimp							1.3					

Note: Zooplankton were not collected in August or October in ZONE III

(continued)

Table A6 (concluded)

Taxa	Date March 18 Replicate A	 Replicate B	 April 15 Replicate A	 Replicate B	 May 13 Replicate A	 Replicate B	 June 17 Replicate A	 Replicate B	 August 19 Replicate A	 Replicate B	 October 14 Replicate A	 Replicate B
d. ZONE IV												
Copepod	206.0	48.5	227.8	2016.4	126.9	160.8	143.1	249.4				
Barnacle	123.6	299.0	923.0	720.1	11.8	12.8	17.0	42.7				
Polychaete	67.4	89.7	1.81	3.13	1.2	1.8						
Crab Zoea			11.79	43.83	2.4	1.2						
Palaemonetes					1.5	0.9	1.9					
Callianassidae							1.9					
Isopoda					0.3		1.9					
Gastropod			0.9									
Anchovy Egg				6.26								
Brown Shrimp						0.6						
Fish Larva					0.3	0.3						

Note: Zooplankton were not collected in August or October in ZONE IV

Table A7

Trawl-Caught Fishes and Invertebrates by Month, Zone, and Tow

Taxa	Zone I Tow Number 1	Zone I Tow Number 2	Zone II Tow Number 1	Zone II Tow Number 2	Zone III Tow Number 1	Zone III Tow Number 2	Zone IV Tow Number 1	Zone IV Tow Number 2
a. March 1975								
VERTEBRATES:								
Atlantic Croaker (*Micropogon undulatus*)	86.3* / 29**	98.1 / 36	78.4 / 23	97.7 / 27	117.1 / 36	106.0 / 21	66.1 / 24	80.4 / 31
Spot (*Leiostomus xanthurus*)	6.1 / 1							
Sea Catfish (*Arius felis*)								
Gulf Butterfish (*Peprilus burti*)		8.1 / 3			1.0 / 1	2.1 / 1		
Southern Stargazer (*Astroscopus y-graecum*)	1.1 / 1				1.1 / 1			
Least Puffer (*Sphoeroides parvus*)				10.8 / 1				
Bighead Searobin (*Prionotus tribulus*)			1.0 / 1					

* Total weight in grams.

** Number of organisms collected.

(continued)

Table A7 (continued)

Taxa	Zone I Tow 1	Zone I Tow 2	Zone II Tow 1	Zone II Tow 2	Zone III Tow 1	Zone III Tow 2	Zone IV Tow 1	Zone IV Tow 2
b. March 1975 (continued)								
INBERTEBRATES:								
Brown Shrimp (*Penaeus aztecus*)	1.0/1						1.4/1	1.6/1
White Shrimp (*Penaeus setiferus*)	14.3/4	27.2/10	77.9/21	50.3/17	33.3/12	35.2/10	70.3/21	59.1/21
Blue Crab (*Callinectes sapidus*)				410.8/3	187.2/2	436.4/2	389.0/2	148.5/1
c. April 1975								
VERTEBRATES:								
Atlantic Croaker (*Micropogan undulatus*)	2.0/1		1.2/1				2.8/1	8.0/2
Spot (*Leiostomus xanthurus*)			5.2/1	12.3/2	7.1/1	40.1/5		
Bay Anchovy (*Anchoa mitchilli*)	2.8/1		4.9/1	9.1/2		9.3/2	3.1/1	0.6/1
Southern Stargazer (*Astroscopus y-graecum*)						1.2/1		
INVERTEBRATES:								
White Shrimp (*Penaeus setiferus*)							15.4/1	25.2/2

(continued)

Table A7 (continued)

	Zone							
	I		II		III		IV	
	Tow Number		Tow Number		Tow Number		Tow Number	
Taxa	1	2	1	2	1	2	1	2
				d. June 1975				
VERTEBRATES:								
Atlantic Croaker (*Micropogon undulatus*)	40.6 / 14	43.5 / 16	120.3 / 37	92.7 / 26	25.6 / 8	40.3 / 11	90.0 / 26	40.3 / 15
Spot (*Leiostomus xanthurus*)	69.6 / 7	87.6 / 10	200.6 / 23	33.8 / 4	7.5 / 1	7.3 / 1	97.4 / 9	69.7 / 7
Sea Catfish (*Arius felis*)	12.9 / 1	32.8 / 2	54.1 / 4	15.6 / 1			15.0 / 1	9.6 / 1
Butterfish (*Peprilus burti*)	2.4 / 4	2.4 / 3	0.8 / 2		0.5 / 1	1.0 / 2	0.3 / 1	
Bay Anchovy (*Anchoa mitchilli*)			0.8 / 2					
Atlantic Thread Herring (*Opisthonema oglinum*)		6.5 / 3	13.7 / 3					
Atlantic Threadfin (*Polydactylus octonemus*)							6.6 / 2	15.8 / 4
Pinfish (*Lagodon rhomboides*)	19.4 / 1		19.8 / 2		17.8 / 1			

(continued)

Table A7 (continued)

Taxa	Zone I, Tow Number 1	Zone I, Tow Number 2	Zone II, Tow Number 1	Zone II, Tow Number 2	Zone III, Tow Number 1	Zone III, Tow Number 2	Zone IV, Tow Number 1	Zone IV, Tow Number 2
				June 1975 (continued)				
VERTEBRATES (continued)								
Gulf Menhaden (*Brevoortia patronus*)							9.5 / 1	19.5 / 1
Sand Seatrout (*Cynoscion arenarius*)			31.0 / 2	1.2 / 1				
Least Puffer (*Sphoeroides parvus*)			1.3 / 1	2.7 / 1				
Inshore Lizardfish (*Synodus foetens*)							26.4 / 1	
Striped Mullet (*Mugil cephalus*)			146.2 / 1					
Atlantic Cutlassfish (*Trichiurus lepturus*)				15.4 / 1				
Florida Pompano (*Trachinotus carolinus*)					3.6 / 1			
INVERTEBRATES:								
Brown Shrimp (*Penaeus aztecus*)	134.3 / 42	145.6 / 49	102.1 / 39	91.6 / 38	76.3 / 29	89.8 / 29	53.4 / 16	62.4 / 22
Blue Crab (*Callinectes sapidus*)	139.4 / 1	270.2 / 1		145.6 / 1		36.0 / 1		

(continued)

Table A7 (continued)

Taxa	Zone I, Tow 1	Zone I, Tow 2	Zone II, Tow 1	Zone II, Tow 2	Zone III, Tow 1	Zone III, Tow 2	Zone IV, Tow 1	Zone IV, Tow 2
e. August 1975								
VERTEBRATES:								
Atlantic Croaker (*Micropogon undulatus*)		45.1 / 5	85.0 / 9	111.2 / 10	84.0 / 7	89.4 / 8	8.8 / 1	16.5 / 2
Spot (*Leiostomus xanthurus*)		35.7 / 2		20.0 / 1		18.2 / 1		
Sea Catfish (*Arius felis*)		25.2 / 11	205.8 / 31	95.2 / 13	1.8 / 1	71.0 / 7		
Crevalle Jack (*caranx hippos*)	2.4 / 1	4.3 / 1		3.7 / 1	10.3 / 1	7.4 / 1	1.0 / 1	2.3 / 1
Harvestfish (*Peprilus alepidotus*)			2.3 / 1		2.1 / 1			2.8 / 2
Black Drum (*Pogonias cromis*)			64.8 / 2	43.2 / 1				
Red Drum (*Sciaenops ocellata*)		170.8 / 1						
Southern Kingfish (*Menticirrhus americanus*)			47.4 / 1					
INVERTEBRATES:								
Blue Crab (*Callinectes sapidus*)				150.3 / 1	285.3 / 1			
Squid (*Loligo* sp.)				20.1 / 1			13.6 / 1	

Table A7 (concluded)

Taxa	Zone I Tow 1	Zone I Tow 2	Zone II Tow 1	Zone II Tow 2	Zone III Tow 1	Zone III Tow 2	Zone IV Tow 1	Zone IV Tow 2
f. October 1975								
VERTEBRATES:								
Spot (*Leiostomus xanthurus*)							38.0/2	36.0/2
Sea Catfish (*Arius felis*)				6.0/1	11.0/2	30.0/2	24.0/2	
Gulf Menhaden (*Brevoortia patronus*)								21.6/1
INVERTEBRATES:								
Brown Shrimp (*Penaeus aztecus*)				1.5/1				
White Shrimp (*Penaeus setiferus*)	53.0/26		0.3/2	1.0/1		8.0/6	39.6/20	
Squid (*Loligo* sp.)			0.4/2	6.0/2				8.8/1

Table A8

Numbers of Benthos Collected Per Square Metre by Sampling Date and Station

a. Polychaetes

Station	Sample Half	Sample Date: March 18	April 15	June 18	August 19	October 14
1	A	86	689	172	2067	947
	D	430	517	258	1636	1636
2	A	603	603	172	603	947
	D	344	430	86	430	430
3	A	517	775	258	86	172
	D	258	689	258	344	258
4	A	517	258	86	344	344
	D	430	172	172	344	344
5	A	86	86	258	430	775
	D	86	86	172	344	1119
6	A	344	258	0	258	344
	D	258	258	172	344	603
7	A	0	344	258	86	258
	D	258	172	86	172	344
8	A	0	86	0	0	258
	D	0	86	0	430	344
9	A	344	172	258	258	689
	D	0	86	172	603	172
10	A	172	172	172	517	775
	D	172	172	258	258	947
11	A	86	430	86	344	1206
	D	0	86	0	517	1033
12	A	86	258	86	517	603
	D	258	258	172	430	1033
13	A					1722
	D					603
14	A					258
	D					517
15	A					1722
	D					603
Average by Date		222	298	150	473	649

(continued)

Table A8 (continued)

b. Nemerteams

Station	Sample Half	Sample Date March 18	April 15	June 18	August 19	October 14
1	A	0	0	0	0	0
	D	0	0	0	0	0
2	A	0	0	0	0	86
	D	0	0	0	0	0
3	A	0	0	0	0	0
	D	0	0	0	0	0
4	A	0	0	0	0	0
	D	0	0	0	0	0
5	A	0	0	0	0	0
	D	0	0	0	86	0
6	A	0	0	0	0	0
	D	0	86	0	0	0
7	A	0	0	0	0	0
	D	0	86	0	0	0
8	A	86	0	0	0	0
	D	0	0	0	0	0
9	A	86	0	0	0	0
	D	0	0	0	0	0
10	A	0	0	0	0	0
	D	0	0	172	0	0
11	A	0	0	0	86	86
	D	0	0	0	0	86
12	A	0	0	0	0	0
	D	0	0	0	86	86
13	A					0
	D					0
14	A					0
	D					0
15	A					0
	D					0
Average by Date		7	7	7	10	14

(continued)

Table A8 (continued)

c. Amphipods

Station	Sample Half	Sample Date: March 18	April 15	June 18	August 19	October 14
1	A	86	172	172	0	0
	D	258	86	86	0	0
2	A	86	0	86	86	172
	D	86	86	0	0	0
3	A	258	0	689	0	0
	D	86	0	344	0	86
4	A	0	172	0	0	86
	D	86	86	86	172	172
5	A	0	1033	0	0	0
	D	86	430	86	0	172
6	A	430	517	0	0	172
	D	344	344	0	0	86
7	A	258	603	0	86	0
	D	0	775	0	0	0
8	A	1033	172	0	0	0
	D	172	0	0	0	86
9	A	172	0	0	86	258
	D	172	344	86	0	86
10	A	258	258	0	0	172
	D	86	430	0	0	0
11	A	172	172	0	0	86
	D	0	172	0	0	86
12	A	86	172	0	0	0
	D	0	258	0	0	0
13	A					0
	D					0
14	A					258
	D					0
15	A					86
	D					86
Average by date		176	262	68	18	72

(continued)

Table A8 (continued)

d. Isopods

Station	Sample Half	March 18	April 15	June 18	August 19	October 14
		Sample date				
1	A	430	0	0	603	172
	D	430	258	258	258	430
2	A	0	0	0	344	517
	D	86	0	0	258	86
3	A	0	0	0	430	0
	D	258	86	0	517	0
4	A	0	0	0	344	172
	D	86	0	86	172	603
5	A	172	947	430	258	517
	D	258	1636	172	689	947
6	A	1120	2325	172	258	86
	D	1808	1808	0	1119	172
7	A	0	1119	0	86	689
	D	86	947	172	0	775
8	A	0	517	0	0	0
	D	0	86	0	0	0
9	A	86	517	0	0	86
	D	86	603	0	86	0
10	A	86	0	172	258	258
	D	0	1033	172	0	172
11	A	517	0	0	0	86
	D	344	430	0	258	0
12	A	86	947	0	0	0
	D	0	430	0	0	0
13	A					344
	D					0
14	A					0
	D					0
15	A					172
	D					0
Average by date		235	570	68	247	240

(continued)

Table A8 (continued)

e. Pelecypods

Station	Sample Half	Sample Date: March 18	April 15	June 18	August 19	October 14
1	A	0	0	86	0	0
	D	0	0	0	0	0
2	A	0	0	86	0	0
	D	0	0	0	0	0
3	A	86	86	0	86	0
	D	86	0	0	0	0
4	A	0	0	0	0	0
	D	0	0	0	86	0
5	A	0	172	0	0	86
	D	258	517	0	0	86
6	A	603	775	0	0	86
	D	603	344	0	0	0
7	A	0	430	0	0	86
	D	86	344	0	0	86
8	A	0	517	0	0	430
	D	0	86	0	0	0
9	A	517	517	0	86	0
	D	517	603	258	86	86
10	A	344	0	0	0	517
	D	517	1033	0	0	0
11	A	0	0	86	0	0
	D	0	430	258	0	86
12	A	172	947	0	0	0
	D	0	430	0	0	0
13	A					0
	D					0
14	A					86
	D					344
15	A					0
	D					172
Average by Date		158	301	32	14	64

(continued)

Table A8 (continued)

f. Gastropods

Station	Sample Half	Sample Date: March 18	April 15	June 18	August 19	October 14
1	A	0	0	0	0	0
	D	0	0	0	0	0
2	A	0	0	0	0	0
	D	0	0	0	0	0
3	A	0	0	0	0	0
	D	0	0	0	0	0
4	A	0	0	0	0	0
	D	0	0	0	0	0
5	A	0	0	0	0	0
	D	0	0	0	86	0
6	A	0	0	0	0	0
	D	86	0	0	0	0
7	A	0	0	0	0	0
	D	0	0	0	0	0
8	A	0	0	0	0	0
	D	0	0	0	0	0
9	A	0	0	0	86	0
	D	0	0	0	0	86
10	A	172	86	0	0	0
	D	0	0	0	0	0
11	A	86	0	0	0	0
	D	0	0	0	0	0
12	A	0	0	0	0	0
	D	0	0	0	0	0
13	A					0
	D					0
14	A					0
	D					0
15	A					0
	D					0
Average by Date		14	3	0	7	3

(continued)

Table A8 (concluded)

g. Cumaceans and Crabs*

Station	Sample Half	Sample Date March 18	April 15	June 18	August 19	October 14
1	A	0	0	0	0	0
	D	0	0	0	0	0
2	A	0	0	0	0	0
	D	0	0	0	0	0
3	A	0	0	0	0	0
	D	0	86**	0	0	0
4	A	0	0	0	0	0
	D	0	0	0	0	0
5	A	0	0	0	0	0
	D	0	0	0	0	0
6	A	0	86**	0	0	0
	D	0	0	0	0	0
7	A	0	0	0	0	0
	D	0	0	0	86**	0
8	A	0	0	0	0	0
	D	0	0	0	0	0
9	A	0	0	0	0	0
	D	0	0	0	0	0
10	A	0	0	0	0	0
	D	0	0	0	0	0
11	A	0	0	0	0	0
	D	0	0	0	0	0
12	A	0	0	0	0	0
	D	0	0	0	258†	0
13	A					0
	D					0
14	A					0
	D					0
15	A					0
	D					86†
Average by date		0	7	0	14	0

* Actual total number collected are 2 cumaceans and 4 crabs.
** Cumaceans.
† Crabs.

Table A9

Grams of Organic Content per Litre of Sediment by Station, Sample, and Month

Station	Sample Half	March	April	June	August	October
1	B	0.0215	0.2204	0.3633	0.1813	0.0747
	C	0.3160	0.6594	0.2516	2.6723	0.2144
2	B	0.0941	0.1574	0.1373	0.0313	0.0616
	C	0.2313	0.1508	0.3174	0.1143	0.0444
3	B	0.1202	0.1956	0.0341	0.0548	0.0560
	C	0.0704	0.4442	0.1411	0.0493	0.0703
4	B	0.1367	0.1326	0.0399	0.0544	0.0575
	C	0.0333	0.0522	0.0322	0.0833	0.0737
5	B	0.1359	0.1261	0.0709	0.0876	0.0230
	C	0.1302	0.9072	0.1041	0.0400	0.0342
6	B	0.0798	0.0706	0.0323	0.0412	0.0301
	C	0.8282	0.0893	0.0547	0.0386	0.0235
7	B	0.0580	0.0962	0.0771	0.0655	0.0606
	C	0.0360	0.5863	0.0737	0.0850	0.0465
8	B	0.00175	0.0749	0.0805	0.0314	0.0203
	C	0.08252	1.1048	0.0932	0.0304	0.0335
9	B	0.1459	0.0927	0.0384	0.0283	0.0246
	C	0.1209	0.0532	0.0680	0.0279	0.0177
10	B	101189	1.0457	0.0565	0.0972	0.0209
	C	0.0683	1.0694	0.0664	0.0348	0.0322
11	B	0.0551	0.4729	0.0840	0.0548	0.0350
	C	0.0725	0.6463	0.1029	0.0371	0.0271
12	B	0.0573	0.0714	0.1400	0.0370	0.0625
	C	0.0780	0.1446	0.0951	0.1189	0.0439
13	B					0.0335
	C					0.0357
14	B					0.0401
	C					0.0343
15	B					0.0644
	C					0.1130

APPENDIX B': Bibliography of the Aquatic Biota of Galveston Bay, Texas

This bibliography was developed as a part of an inventory and assessment of the aquatic biota of the Corps Bolivar Peninsula habitat development site in Galveston Bay, Texas. Some listed references do not deal with research in Galveston Bay but are pertinent because the studies were conducted on organisms found in the Galveston estuarine system.

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Lyon, James M

Habitat development field investigations, Bolivar Peninsula marsh and upland habitat development site, Galveston Bay, Texas; Appendix C: Baseline inventory of aquatic biota / by James M. Lyon and Kenneth N. Baxter, National Marine Fisheries Service, Southeast Fisheries Center, Galveston Laboratory, Galveston, Tex. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1978.

43, 33, 25 p. : ill. ; 27 cm. (Technical report - U. S. Army Engineer Waterways Experiment Station ; D-78-15, Appendix C)

Prepared for Office, Chief of Engineers, U. S. Army, Washington, D. C., under Interagency Agreement No. WESRF 75-101 (DMRP Work Unit No. 4A13D)

Appendix B: Bibliography of the Aquatic Biota of Galveston Bay, Texas.

Literature cited: p. 25-26.

(Continued on next card)

Lyon, James M

Habitat development field investigations, Bolivar Peninsula marsh and upland habitat development site, Galveston Bay, Texas: Appendix C: Baseline inventory of aquatic biota ... 1978. (Card 2)

1. Aquatic animals. 2. Biota. 3. Bolivar Peninsula. 4. Dredged material. 5. Field investigations. 6. Galveston Bay. 7. Habitats. 8. Marshes. 9. Sampling. 10. Sediment. 11. Waste disposal sites. I. Baxter, Kenneth N., joint author. II. United States. National Marine Fisheries Service. Southeast Fisheries Center. Galveston Laboratory. III. United States. Army. Corps of Engineers. IV. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; D-78-15, Appendix C.

TA7.W34 no.D-78-15 Appendix C